Popular Astronomy.

Vol. VI. No. 9. NOVEMBER, 1898. Whole No. 59.

PHOTOGRAPHIC FLASHES FROM HARVARD OBSERVATORY.

HARRIET RICHARDSON DONAGHE.

FOR POPULAR ASTRONOMY.

It seems fitting that the locality where Asa Gray and Louis Agassiz studied the intricate forms of plant life and the secrets of rock formation, where Pierce demonstrated the abstruse problems of higher mathematics and Wyman the delicate functions of the human machine, where William B. Rogers founded the Massachusetts Institute of Technology and where the "American Association for the Advancement of Science" had its birth, should see the rise of a sister society dedicated to that most poetic and at the same time most exact of sciences, astronomy, with its inseparable companion and counterpart, the science of physics. The recent conference of astrophysicists at Harvard Observatory, though quietly convened and unheralded save among the *cognoscenti*, will become memorable not only for distinct steps taken in the advance of science and the discussion of theories and discoveries in this ever fascinating field of research, but also as marking the foundation of a new society, a brotherhood of astronomers and physicists, whose union will be their strength and whose combined wisdom and mutual aid will disseminate among mankind the benefits revealed by the white light of truth. From this nucleus of representative men, resolving to form themselves into a permanent American Society of Astrophysicists, may spring an association whose jubilee may be rendered glorious by discoveries as yet undreamt of, as electrifying as that of the Roentgen rays, or as capable of practical application as that of the phonograph or the telephone.

At the dedication of the Yerkes Observatory in 1897 was held a gathering of astronomers at Williams Bay, Wisconsin, and so helpful did this meeting prove, that in response to the invitation of Professor Edward C. Pickering, a similar conference assembled on the morning of August 18th, 1898, in the residence of the director of Harvard Observatory to convene a session of three days at Cambridge. The spacious mansion of Professor Pickering formed an ideal place for the meeting of a convention, while the

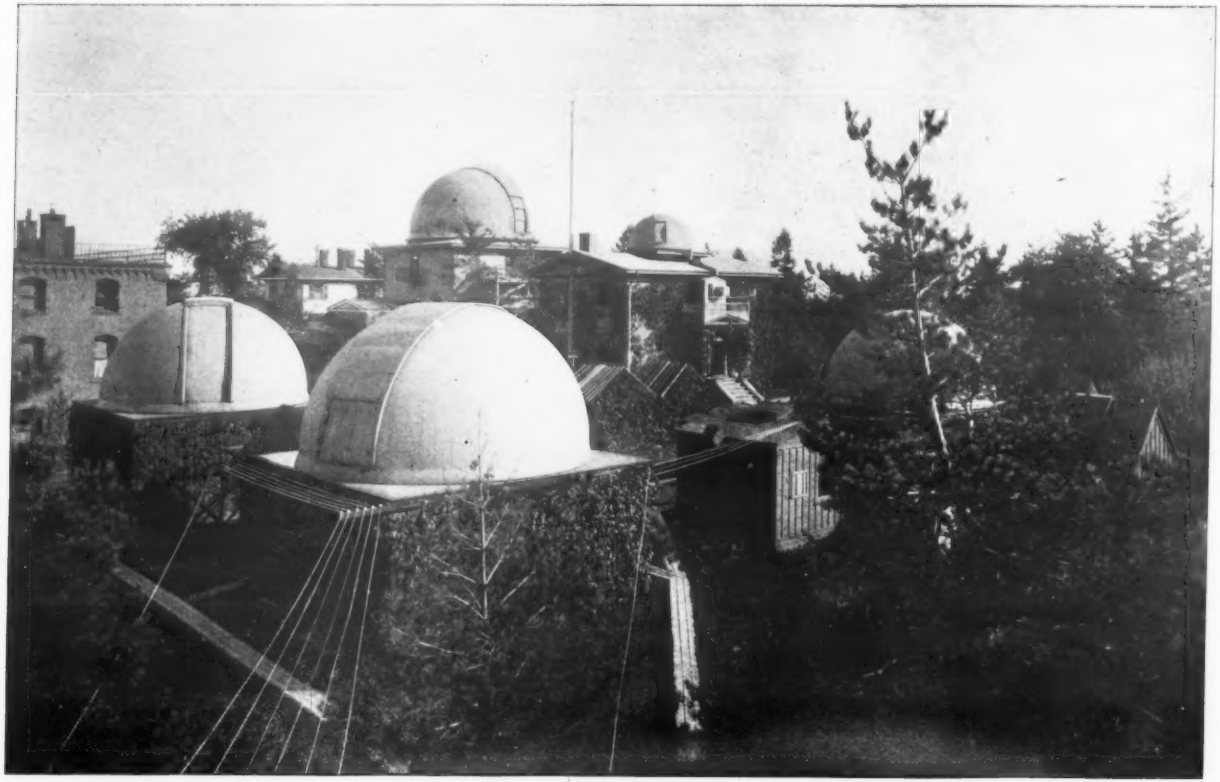
gracious dignity of the director and the hospitality of his stately wife, who received their guests with a cordial greeting, gave the serious purpose of the assemblage a touch of festivity and saved even the non-scientist from feeling out of his element.

"Charts and diagrams, to add, divide and measure."

gave evidence of the heavy work laid out for the *savants*, but behind them gleamed the the snowy outlines of the bust of some honored ancestor, the rich coloring of a family portrait, or the sparkle of a jewelled miniature, in the artistic setting of a private drawing room. Professor J. R. Eastman of the Naval Observatory, Washington, was called to the chair and the first paper, "Personal Equation in Transit Observation," by Professor Arthur Searle, was read. But how can the untutored in celestial affairs, the mere telescopic observer, as it were, viewing the gyrations and scintillations of the astronomic mind, as, bounding along its orbit of specialized knowledge, it throws off star dust of technical information, hope to catch more than a faint reflection, a wandering ray, from the brilliancy which dazzles his eye, unaccustomed to such piercing vision? Even in Boston it has been whispered with bated breath by one aspiring yet despairing seeker after sweetness and light that he "didn't believe even the governor of the Commonwealth or the mayor of Boston understood *all* those hard words!" So accurately must these minute calculations be carried out that much discussion followed Professor Searle's paper in regard to the "constant of aberration," or in other words the sum of the discrepancies resulting from transmission through the personal medium, the variation in the axis of the telescope, or the refraction of a ray of light in passing through the layers of the atmosphere.

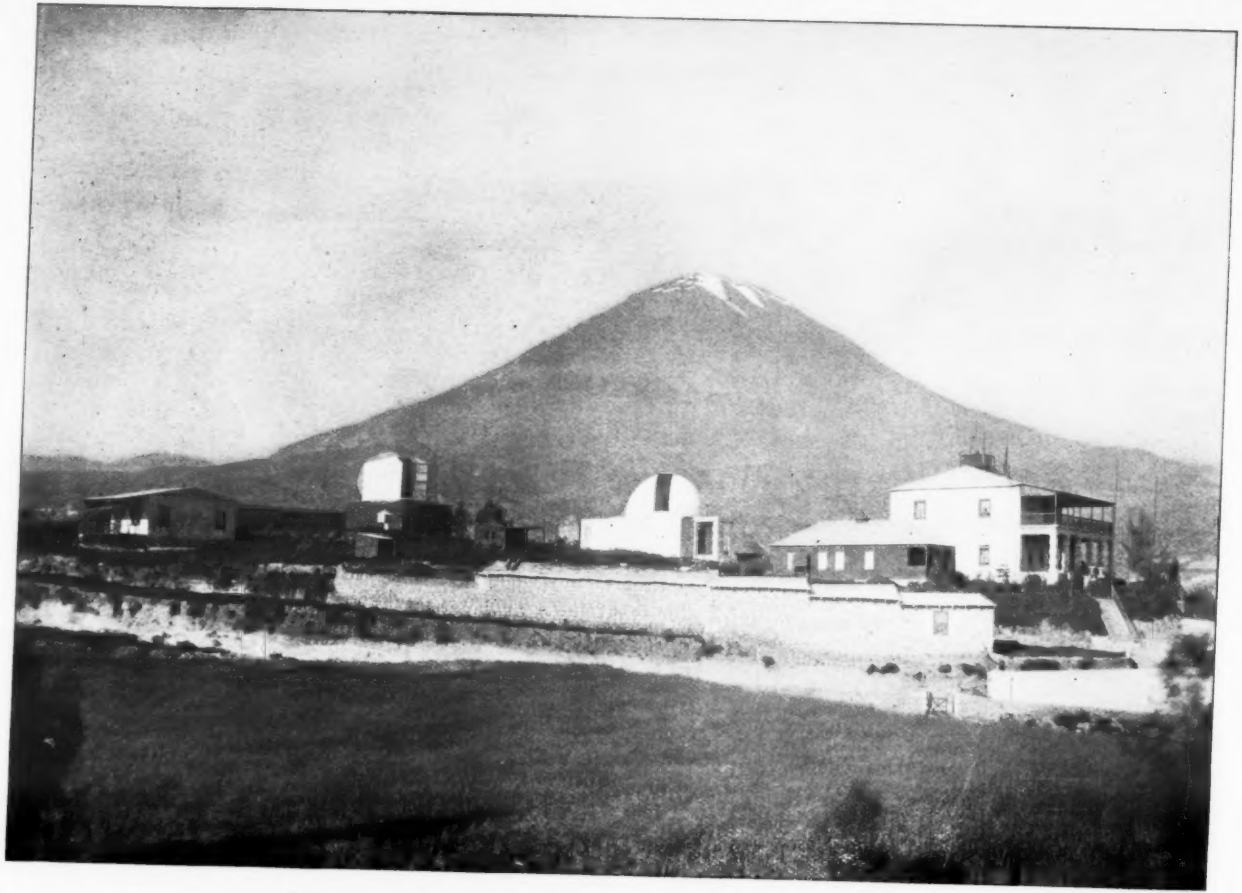
Professor George C. Comstock, of Madison, Wisconsin, in a talk delivered in a crisp, concise and comprehensible style, carried out a somewhat similar line of thought in regard to "Investigations Relating to Zenith Telescope Latitudes," in the course of which he called attention to various causes which may occasion these errors in observation, such as the physical condition of the observer, the tilting of the strata of the atmosphere, the differing conditions of the Earth's surface, as at Naples where the meridian passes to the north over land and to the south over water, producing daily fluctuations of temperature, and even the effect of a current of air from a near-by chimney. The conclusions generally drawn from these propositions seemed to be that the zenith telescope could not be employed for this purpose with wholly satisfactory results.

PLATE IX.



HARVARD COLLEGE OBSERVATORY.

PLATE X.



AREQUIPA STATION OF HARVARD COLLEGE OBSERVATORY.

The contribution of Mrs. M. Fleming, read by Mr. Pickering, Director, on "Stars of the Fifth Type in the Magellanic Clouds" contained some important statements in reference to the stars having spectra consisting mainly of bright lines, designated as Fifth Type. Of these stars, which all lie in the Milky Way and in the Magellanic clouds, ninety-two have been discovered up to the present time, all but thirteen having been found by the aid of photographs during the last fourteen years.

In conclusion Professor Pickering said that Mrs. Fleming had omitted to mention that of these seventy-nine stars nearly all had been discovered by herself, whereupon Mrs. Fleming was compelled by a spontaneous burst of applause to come forward and supplement the paper by responding to the questions elicited by it. One of the most interesting subjects of the day was that of "Variable Stars in Clusters," by Professor Solon I. Bailey, who had charge for five years of the Observatory at Arequipa, Peru. This station at an elevation of 8,060 feet, the highest permanent astronomical Observatory, has in connection with it a series of meteorological stations crowning the summits of the Andes, one of which, El Misti, is situated at an altitude of 19,200 feet. The equipment at Arequipa includes the splendid 24-inch Bruce photographic telescope and others for either visual or photographic work, also a transit photometer, so that photographs of bright stars crossing the meridian may be made south of the equator and the southern heavens studied and photographed in the same manner as in the northern hemisphere. The discoveries of Professor Bailey by photographic methods have been crowned with such success that numerous plates have been obtained of close clusters in which changes in brightness in many of the individual stars may easily be distinguished and which could not have been visually observed through instruments of the same size. Twenty clusters have been investigated up to the present date, the percentage of variables in these ranging from less than one to fifteen per cent, but averaging in seventeen clusters three per cent, and the proportion appearing to be greater among the bright stars.

Before assimilating any more mental pabulum, the guests were invited to partake of the hospitality of Mr. and Mrs. Pickering at luncheon in the dining room of the residence.

An afternoon session followed with papers from Professors G. W. Hough, Charles Lane Poor and Albert S. Flint, and the entertainment was completed by an interesting tour of the Observatory, which has been selected as the American centre for the transmis-

sion of astronomical discoveries, as that at Kiel, Germany, with which constant cable communication is maintained, is the chosen point of distribution on the continent of Europe. An annual income of $50,000 is expended at the Harvard Observatory in research, the results of which are preserved in the annals, now numbering about forty quarto volumes, and twenty-one men and nineteen women find almost constant employment in making and recording these investigations.

The 15-inch equatorial telescope, at the time of its construction in 1847, one of the finest and largest in the world, still holds the place of honor in the central dome, while in other domes about the grounds are the smaller telescopes, recorders, reflectors, photometers and the 8-inch meridian circle.

The brick building, formally christened at this conference the Astrophotographic Building, is presided over by Mrs. Fleming whose researches and discoveries have largely been in this special line of work. A complete pictorial history of the aspect of the sky during the last ten years is here preserved by means of one hundred thousand photographs taken both in Cambridge and Peru, for these insatiate star-gazers, want nothing short of—the heavens! Charts and spectra of all the stars from the north to the south pole furnish a study of absorbing interest, while even broken photographic plates are mended and filed away in the "hospital" for occasional reference. An annual sum is given by Mrs. Henry Draper to be used in continuing photographic research along the lines to which her husband, who was the first successfully to photograph the spectrum of a star, proposed to devote his life. The central room where the comparison of charts and photographs is carried on is known as the Draper Memorial Room.

In an adjoining section, Professor Bailey explains his diagrams of variables, some recent photographic plates of clusters being contrasted with a drawing made from calculation by Bond in 1849, showing the advantage of the modern process in obtaining a full and accurate reproduction. This inspiring theme of stellar photography and the wonderful avenues opened by it was the subject of an able lecture delivered on the evening of August 18th at the Institute of Technology by Professor E. E. Barnard, an acknowledged authority on this branch of the science, which was illustrated with beautiful sidereal photographs. A treatise of technical interest, also illustrated by lantern pictures, "On the Spectra of Stars of Secchi's Fourth Type" was read by Professor George E. Hale, Director of the Yerkes Observatory.

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VIEW OF ARE[illegible]

(El Misti Obscured by Clouds.)

PLATE XI.

VIEW OF AREQUIPA STATION.

(El Misti Obscured by Clouds.)

PLATE XII.

ABOVE THE CLOUDS. VIEW FROM MOUNT HARVARD, PERU.

With Professor Hale as chairman, the second session of the conference opened on the following morning with a discussion of subjects of general interest to astronomers, the topics under consideration being the formation of an organized society, the coming total eclipse of the Sun on May 28th, 1900, and the November meteors, which, according to Professsor Barnard, may be photographed with an ordinary portrait camera, thus opening a new field to the amateur. The ensuing paper was an argument by Dr. Harold Jacoby, of Columbia University, on "Photographic Researches near the Pole of the Heavens," relating especially to photographs taken at Helsingfors where by exposing the plate of the telescopic camera at regular intervals a series of astral impressions was obtained in the arc of a circle, thus aiding in the determination of the constants of aberration and notation. The meeting closed with a clever paper by Miss Agnes M. Clerke "On the Spectra of Certain Nebulæ."

By invitation of the President and Fellows of Harvard University, the members of the conference were honored with a luncheon served in University Hall, a building designed by Bulfinch of State House fame, where have been entertained Presidents Monroe, Jackson and Van Buren and the Marquis de Lafayette, and where at the present day from the walls look down the countenances of worthies and benefactors whose portraits have been painted by artists from the time of Copley to that of Bonnat. In the afternoon an opportunity was given to visit the various foundations of Harvard.

At the final gathering of the astronomers on Saturday, August 20th, Miss A. C. Maury, a niece of Dr. Henry Draper, contributed a scholarly essay "On the K lines of Beta Aurigæ," and was followed by Professor G. W. Myers, University of Illinois, who made some learned remarks on the Variable Star U Pegasi.

The culminating treat to the conference, and one capable of appreciation by every visitor, whether he fully comprehended the Stellar Parallax and the Effective Insulation of Mercurial Horizons or not, was the afternoon trip to the Blue Hill Observatory, made possible through the kindness of Professor A. Lawrence Rotch, who maintains and directs this meteorological station. The excursion was made by railway to Readville, where wagonettes were in waiting to convey the invited guests to the foot of Blue Hill, though many of the scientists, as eager to mount an up-grade awheel as to scale the steep ascent of the rough path of knowledge, preferred to betake themselves to bicycles for a portion of the trip. A charmingly wooded footpath, shaded by

Above the Clouds. View from Mount Harvard, Peru.

thickets of birch and oak, winds up to the summit of Blue Hill, where a glorious panoramic view, extending from Boston harbor to Middlesex Fells, with tracts of woodland and meadow dimpling under the soft cloud-shadows, lies spread before one on every side. An interesting collection of instruments embodying the latest inventions and improvements is contained in the Meteorological Observatory, which is divided into observation and sleeping rooms and an attractive library. Weather conditions are observed three times a day at the summit and base of Blue Hill, and a continuous record is kept by means of self-recording instruments. A special feature is the exploration of the upper air by the use of kites, capable of lifting a meteorograph weighing three pounds. This curious machine contains four instruments, a barograph, a hydrograph, a thermograph and an anemometer, and thus records four kinds of observations at the same time, besides indicating the direction of the wind from the movement of the kite. A kite ascension was arranged for the visitors, who then inspected the kite steam-windlass, an engine for controlling the wire attached to the kites, which are also regulated by elastic bridles. A dynamograph records the exact amount of wire out at any moment and when the 20,000 feet, or about four miles, of wire which are wound upon the reel are fully let out, the kite has been enabled to reach a height of 11,800 feet or the equivalent of more than two miles in a vertical line. The experience at Blue Hill brought the astrophysical conference to a delightful close, but a supplementary session was called the following week to consider some valuable papers still to be discussed and to express the thanks of the conference to Professor Pickering, director of Harvard College Observatory, and others who had rendered the occasion so enjoyable and profitable. Many visitors availed themselves on clear nights of the proffered courtesies of the Observatory to catch those elusive glimpses of the

"Planets and the pale populace of heaven."

which are the astronomer's reward for days of devoted toil and patient waiting.

We have heard a great deal of late, in Admiral Erben's phrase, of "the man behind the gun," to whose skill and steady nerve we owe our victories in far-off tropic seas or in the desperate charge through thicket and jungle. We owe another debt to the man of science who guides with trained hand and unerring eye the instruments of his art to attain those conclusions which mitigate the terrors of war and make glorious the achievements of peace. He

may claim in the language of Euclid, "The empire of the Ptolemies shall crumble. . . . . it and Greece and Rome shall all pass away; but my words shall not pass away. They are the revelations of formal science and all coming ages shall build on what I have here wrought."

SOME REMARKS REGARDING THE PARALLAXES OF 61 AND 61² CYGNI AND THE PROBABLE PHYSICAL CONNECTION OF THESE TWO STARS.*

HERMAN S. DAVIS.

In *Contribution No. 13* from the Observatory of Columbia University the writer has presented a discussion of the measures of certain photographic plates made by Dr. L. M. Rutherfurd in 1871-4 for a determination of the parallax of 61 Cygni. The main result given in that publication is summarized by the two lines:

$$\text{Parallax of } 61^1 \text{ Cygni} = + 0''.360 \pm 0''.015$$
$$\text{Parallax of } 61^2 \text{ Cygni} = + \quad .288 \pm 0 \quad .028$$

The object of this paper is to suggest what these results signify.

It should be explained first that the star usually known as 61 Cygni is really not one star, but two stars whose angular separation was about 19″ in 1874. That one of the two which crosses the meridian first is designated by the exponent or the subscript "one" attached to the number of the star (*i. e.* 61^1) and is spoken of as "the preceding" star; in like manner "the following" star is 61^2 Cygni. These stars are of nearly the same brilliancy, 5.7 and 5.6 magnitude respectively; and they are notable for having large proper motions which are very nearly the same both in amount and in direction. These are, annually in distance:

$5''.21$ for 61^1 Cygni and $5''.15$ for 61^2 Cygni,

and in direction:

$51°.70$ for 61^1 Cygni and $53°.58$ for 61^2 Cygni

for the epoch 1874. The proper motions of these stars were first

* A paper prepared at the suggestion of Professor J. K. Rees, director of the Observatory of Columbia University, and read by Professor Upton (in the absence of the author) at the Astronomical Conference held at Harvard College Observatory 18-20, 1898.

detected in 1804 by Piazzi, the Sicilian astronomer, while engaged on his great catalogue.

As the preceding star is the northern one, these angles of direction would indicate that the distance between them is increasing, and direct measures verify this. Whether this will continue indefinitely or not depends on whether the two stars are only *optically* double (though really separated by a wide interval of space by reason of one being more remote from the Solar System than the other), or are *physically* connected forming a binary system. This is a question which has adherents on each side, some claiming that the variations of measures of distance from Piazzi's time to the present show an orbital motion, while others claim that such variations are due to accidental or systematic errors of observation. But the question lies so near the limit between the determinable and the indeterminable that a method of investigation quite remote from observation has been invoked for its solution. Hence we find that, hitherto, the theory of probabilities has been used somewhat more effectively in favor of orbital motion, than has been the better established theory of motion of matter acted on by gravitation. Thus all claimants for rectilinear motion have been met by the statement that whether the *measures* are conclusive or not, the *chances* are many millions to one against two stars of such an unusually large proper motion being placed accidentally in such close juxtaposition in line of sight from the Earth at this particular age in the Earth's history. This introduces, as you will notice, many limiting circumstances and presupposes (what may not yet be denied) that 5″ *is* an unusual and very large proper motion; though it should be remembered that astronomers do not yet have the data needful for determining the motions of more than ten thousand stars, say, out of the more than ten millions within modern telescopic reach. Only within a few months have we been aroused by Kapteyn's discovery of a motion of 8″.9 for one of the southern stars. This gives us a "lightning-flier," indeed, when compared with even the "runaway star," 1830 Groombridge. How many other such rapidly moving stars like this are to be detected from present photographic plates when compared with those to be made in the future is itself a problem in probabilities, the solution of which will affect very materially the data on which to recompute Wilhelm Struve's conclusion, that*

* . . . Nexus itaque physicus inter stellas 61 Cygni plus centies millies est probabilior, quam crastinus Solis ortus secundum experientiam historicam plus quinque millium annorum exspectandus. . . .

F. G. W. Struve in *Stellarum Fixarum*, p. CCIII.

"The physical connection of 61 Cygni is a hundred thousand times more probable than that tomorrow's Sun should rise, even when that expectation is based on an experience of five thousand years."

Otto Struve refers to this conclusion in his paper on the parallax of 61 Cygni in the following words:*

"The probability of a physical connection of these two stars, deduced from researches upon the distribution of stars on the celestial vault and from the approximate equality, both in amount and in direction, of their large proper motion, is so great that this connection cannot be reasonably doubted."

This seems to be entirely on the assumption that the question is to be attacked only by the methods of *a priori* reasoning. He then continues:†

"The two stars have *consequently* the same parallax, . . . etc.," thus accepting the statement as a necessary conclusion, logically consistent and beyond doubt or argument. Yet the elder Struve, in stating the probability of 61 Cygni being a binary star, expressly starts with the assumption‡ "that their parallaxes are unknown . . . " hence as soon as the parallaxes of the two stars *are* known the "probability" dwindles away and becomes as absurd as is Otto Struve's "reasoning in a circle."

Moreover, I need hardly remind you that even when conclusions logically consistent with the assumptions have been deduced in accordance with the "theory of probabilities" they are not always nevertheless in agreement with events: or, stated in another way, that which is concluded to be exceedingly improbable does sometimes happen in a fewer number of trials than its "probability" would seem to justify,§ and the "probability" against an event never taking place is in some cases completely over-ruled by its actual occurrence. To quote the idea of Professor Barnard in *Sidereal Messenger*, Vol. X, page 18:

Anyone familiar with the discovery of comets and the comparative scarcity of the same, and who can appreciate the vast expanse of the heavens, in which the average comet is the merest speck . . . will know that there are many millions of chances

* . . . La probabilité du nexe physique des deux astres, déduite des recherches sur la distribution des étoiles sur la voûte céleste et de l'égalité approximative, tant en quantité qu'en direction, de leur énorme movement propre, est si haute que ce nexe peut pas être raisonnablement tiré en doute.

† . . . Les deux étoiles auront donc la meme parallaxe, . . . etc.

‡ . . . si parallaxem non cognitam supponimus. . . .

§ Of course it is obvious in such a case that, after the exception has occurred, the "probability" becomes renewed in all its force with regard to another similar occurrence—but the first exception still stands in controversion of the original "probability."

against the discovery of two new comets within a few minutes of each other so as to be in the same field of view of a 27-inch telescope, and yet the two being in no way physically connected.

Yet this actually occurred in the case of the comets of Zona and of Spitaler in 1890, and is one of the most remarkable co-incidences known to the astronomical world.

This illustration and the trend of my argument is not for the purpose of eliminating entirely all considerations based on the theory of probabilities, (which is better than nothing when facts are not available), but to assist in removing from our minds some of the lingering prejudices of tradition regarding this remarkable star, 61 Cygni.

Referring once again to the elder Struve's *Stellarum Fixarum* (page ccxxi), we find, after a table of the measures by various astronomers from Bradley in 1753.8 down to his own in 1851.8, the following statement, in which the italics are by Struve himself:*

"The agreement between the observed and the calculated places are such that I can unhesitatingly declare that the *relative motion of the two stars forming 61 Cygni has shown not the least deviation from a straight line which could be recognized by observations during the course of a hundred years*,—a circumstance marvelous in the highest degree and wholly unexpected by me."

Nearly half a century of additional observations leaves this statement just as true as when first written, yet no star has been more carefully observed for this very purpose. Yet, also, in his calculation of the probability of the physical connection of the two stars he does not include the consideration that the plane of any orbit, (such as could be assigned in satisfactory accord with the necessarily long period admitted by claimants of the binary nature), must be nearly perpendicular to the line of sight from the Earth, if its vast magnitude (indicated both by length of period and by present separation of 21″ at a distance great enough to give a parallax of .36″) should remain undetected by a noticeable cyclical change of parallax. To be sure refinement of observations and of instruments has not yet reached the stage when orbital motion can be detected or verified by *variation* of parallax in a long series of years; but that Peters' orbit is anything like tangent to the celestial sphere is not claimed. That the two

* Consenus, qui inter relationes observatas et eas, quae calculo deductae sunt, obtinet, talis est, ut nullas dubito quin declarem, *motum relativum duarum stellarum in 61 Cygni nexarum ne minimam quidem a linea recta deflexionem, quae in observationibus cognosci posset, centum annorum spatio prodidisse.* Res sane maximopere mirabilis, mihique valde inexspectata.

stars are, therefore, by chance, at the present time so situated in their relative orbit as to be at or near the extremity of a diameter at right angles to the line of sight, so that they should have the *same* parallax, is so highly improbable as to shift the burden of proof (in the light of existing data, at least) to anyone who claims the *equality* of parallax, even if we should be willing to admit that the system is a binary one. Because it *is* possible by present methods to determine a *difference* of parallax between two close stars: were this not true all parallax researches thus far undertaken have been entirely wasted exertion.

That the two stars under discussion have a difference of parallax of $0''.072 \pm 0''.028$ is the conclusion reached in my discussion of the Rutherfurd measures as stated in the first paragraph of this paper. If this result be a proper interpretation of Nature, we have another illustration of facts upsetting probabilities. So let us see if there is any evidence confirmatory of this difference of parallax deduced from the Rutherfurd photographs.

The best series of measures ever made of the distance between these two stars is that published by Professor Wilsing of Potsdam in *Sitzungsberichten der Königl. Preuss. Akademie der Wissenschaften*, 1893, Bd. 40. From the variations of distance there given he announced the discovery that the preceding star is itself a double, the companion being invisible. He also publishes a curve to show the deviations of the distances measured at different times from the mean of all. His method of taking the photographs and his discussion of them are unique and well worthy of study and imitation, but I must refer you to the original paper for the details. I wish to remark, however, that it is greatly to be regretted that points numbered 1, 2, 3, and 4 of his curve are determined by only 4, 2, 2, and 2 exposures on 2, 1, 1, and 1 plates respectively, in contrast with the other points which are determined by the means of from 11 to 40 exposures; and that the most critical portion of the curve (that from January 15, 1892, to January 13, 1893) is determined by two points only, from 15 and 11 exposures on only 5 and 4 plates respectively.

The significance of this is: that it is only necessary to shift slightly the position of these two weakest points in his curve to make it correspond in nearly every detail and peculiarity with the curve which would be obtained by the assumption of a difference of parallax instead of a dark companion to the preceding star. Hence I thought it advisable to form equations of condition from Wilsing's measures and by the introduction of a parallax-term see what value of the difference of parallax, if any, might be de-

duced from them. The result was 0″.088 ± 0″.012 which is in very close agreement with the 0″.072 from the Rutherfurd plates by measures of both distance and position-angle; and may be regarded as strongly confirmatory of that result. For surely those who still adhere to the "probabilities" in the case must admit that even *they* argue against the co-incidence of two such results if those results be not the true interpretation of a single fact of Nature.

Moreover, if we tabulate all values of parallax of each of these stars as determined by preceding investigators and combine all these individual results into means by weights proportional to the reciprocal of the square of the probable error, we have the mean of previous determination of the

$$\text{Parallax of } 61^1 \text{ Cygni} = 0''.417 \pm 0''.0216$$

and, in like manner excluding my own determinations:

$$\text{Parallax of } 61^2 \text{ Cygni} = 0''.335 \pm 0''.0076,$$

which give a difference of parallax:

$$61^1 - 61^2 = 0''.082 \pm 0''.023$$

and if the Rutherfurd results be included this becomes:

$$61^1 - 61^2 = 0''.048 \pm 0''.014.$$

Let us now tabulate these differences of parallax:

Davis' Rutherfurd,—direct measures of distance	+ 0″.128	± ″.053
Davis' Rutherfurd,—direct measures of angles	+ .051	.032
Adopted Mean =	+ 0″.072	± ″.028
Davis' Wilsing,—direct measures of distance	+ .088	.012
Wilsing's $(61^1 - 6) - (6^2 - 6)$*	+ .048	.031
Mean of all determinations previous to Rutherfurd =	+ .082	.023
Mean of all determinations including Rutherfurd =	+ .048	.014

The magnitude and accordance of these values when considered in connection with their respective probable errors leave little room for doubt as to the reality of the difference of parallax detected by the measures of the Rutherfurd plates. So that if 61^1 Cygni be really a binary system of which one member is a dark body† it is nevertheless far removed from the influence of 61^2 Cygni, which would account for the as-yet unproved‡ orbital motion of 61^1 and 61^2 around a centre of gravity common to the

* *Publicationen des Astrophysikalischen Observatoriums zu Potsdam:* Nr. 36, page 148.

† *Publications of the Lick Observatory*, Vol. II, 1894, page 122. Burnham records his inability to see at 1889.463 and 1889.502 a companion to either star, though using the 36-inch telescope with powers up to 1000.

‡ *Monthly Notices*, Vol. XXXV, page 323. *Astr. Nach.*, Vol. 132, pages 87 and 199. *Sidereal Messenger*, Vol. X, pages 1 and 13.

two. For, as I have already attempted to show, the probabilities in favor of the existence of such orbital motion, if they really have the *same* parallax, are fully as strong as are those against juxtaposition in line of sight of two stars having so nearly the same large apparent motion, if they are really separated in space by the distance which this *difference* of parallax indicates.

The evidence here presented as to a difference of parallax is at any rate of sufficient weight to demand a more extended series of photographic measures of the same degree of precision as Wilsing's and extending over more than two years. Perhaps Professor Wilsing will himself be willing to continue his series of plates. It is also highly desirable to reinforce the evidence of a variable proper motion of 61^1 by independent methods, such as is afforded by the spectroscope, for example.

While, therefore, in this paper—but more particularly in the published paper on *The Parallaxes of* 61^1 *and* 61^2 *Cygni*—a plea has been presented for the adoption of a belief that these two stars are moving through space independently of each other and separated from each other by an interval represented by two and one quarter "light years," nevertheless I have not purposed to leave on your minds the impression that I regard this difference of parallax as an entirely indisputable fact. I recognize some of the weaknesses of the arguments and the insufficiency of observational data. The preceding paragraph bears testimony to this.

But since it is the well accepted policy of scientific investigators to accept provisionally as true, until disproved (if such should be its ultimate fate) that which has the greatest direct evidence in its favor, it seems to me we are called on to believe the conclusion of this paper: *that the two stars of 61 Cygni are too remote from each other to form a binary system:* until much more evidence, spectroscopic or other, shall be accumulated to disprove (if it should) that such a conclusion is valid.

THE OBSERVATORY, COLUMBIA UNIVERSITY, New York City,
August 6th, 1898.

RECENT ADVANCES IN PHYSICAL SCIENCE.*

Having kept you for the last half hour rigorously chained to earth, disclosing dreary possibilities, it will be a relief to soar to the heights of pure science, and to discuss a point or two touching its latest achievements and aspirations. The low-tempera-

* The Presidential address of Sir William Crookes, F. B. S., to the British Association last week contains the following interesting *résumé* of recent advances in physical science:—

ture researches, which bring such renown to Professor Dewar and his laboratory in the Royal Institution, have been crowned during the present year by the conquest of one of Nature's most defiant strongholds. On May 10 last Professor Dewar wrote to me these simple but victorious words: "This evening I have succeeded in liquefying both hydrogen and helium. The second stage of low temperature work has begun." Static hydrogen boils at a temperature of 238° C. at ordinary pressure, and at 250 C. in a vacuum, thus enabling us to get within 23° C. of absolute zero. The density of liquid hydrogen is only one-fourteenth that of water, yet in spite of such a low density it collects well, drops easily, and has a well-defined meniscus. With proper isolation it will be as easy to manipulate liquid hydrogen as liquid air.

The investigation of the properties of bodies brought near the absolute zero of temperature is certain to give results of extraordinary importance. Already platinum resistance thermometers are becoming useless, as the temperature of boiling hydrogen is but a few degrees from the point where the resistance of platinum would be practically nothing or the conductivity infinite.

Several years ago I pondered on the constitution of matter in what I ventured to call the fourth state. I endeavoured to probe the tormenting mystery of the atom. What *is* the atom? Is a single atom in space solid, liquid, or gaseous? Each of these states involves ideas which can only pertain to vast collections of atoms. Whether, like Newton, we try to visualise an atom as a hard, spherical body, or, with Boscovitch and Faraday, to regard it as a centre of force, or accept the vortex-atom theory of Lord Kelvin, an isolated atom is an unknown entity difficult to conceive. The properties of matter—solid, liquid, gaseous—are due to molecules in a state of motion. Therefore, matter, as we know it, involves essentially a mode of motion; and the atom itself—intangible, invisible and inconceivable—is its material basis, and may, indeed, be styled the only true *matter*. The space involved in the motions of atoms has no more pretension to be called matter than the sphere of influence of a body of riflemen, the sphere filled with flying leaden missiles, has to be called lead. Since what we call matter essentially involves a mode of motion, and since at the temperature of absolute zero all atomic motions would stop, it follows that matter, as we know it, would at that paralysing temperature probably entirely change its properties. Although a discussion of the ultimate absolute properties of matter is purely speculative, it can hardly be barren, considering that in our laboratories we are now within moderate distance of the absolute zero of temperature.

I have dwelt on the value and importance of nitrogen, but I must not omit to bring to your notice those little-known and curiously related elements which during the past twelve months have been discovered and partly described by Professor Ramsay and Dr. Travers. For many years my own work has been among what I may call the waste heaps of the mineral elements. Professor Ramsay is dealing with vagrant atoms of an astral nature. During the course of the present year he has announced the existence of no fewer than three new gases—krypton, neon and metargon. Whether these gases, chiefly known by their spectra, are true unalterable elements, or whether they are compounded of other known or unknown bodies, has yet to be proved. Fellow-workers freely pay tribute to the painstaking zeal with which Professor Ramsay has conducted a difficult research, and to the philosophic subtlety brought to bear on his investigations. But, like most discoverers, he has not escaped the flail of severe criticism.

There is still another claimant for celestial honours. Professor Nasini tells us he has discovered, in some volcanic gases at Pozzuoli, that hypothetical element Coronium, supposed to cause the bright line 5316.9 in the spectrum of the Sun's corona. Analogy points to its being lighter and more diffusible than hydrogen, and a study of its properties cannot fail to yield striking results. Still awaiting discovery by the fortunate spectroscopist are the unknown celestial elements Aurorium, with a characteristic line at 5570.7—and Nebulum, having two bright lines at 5007.05 and 4959.02.

The fundamental discovery by Hertz, of the electro-magnetic waves, predicted more than thirty years ago by Clerk Maxwell, seems likely to develop in the direction of a practical application which excites keen interest—I mean the application to electric signalling across moderate distances without connecting wires. The feasibility of this method of signalling has been demonstrated by several experiments at more than one meeting of the British Association, though most elaborately and with many optical refinements by Oliver Lodge at the Oxford meeting in 1894. But not until Signor Marconi induced the British Post Office and foreign governments to try large-scale experiments did wireless signalling become generally and popularly known or practically developed as a special kind of telegraphy. Its feasibility depends on the discovery of a singularly sensitive detector for Hertz waves —a detector whose sensitiveness in some cases seems almost to compare with that of the eye itself. The fact noticed by Oliver

Lodge in 1889, that an infinitesimal metallic gap subjected to an electric jerk became conducting, so as to complete an electric circuit, was re-discovered soon afterwards in a more tangible and definite form, and applied to the detection of Hertz waves by M. E. Branly. Oliver Lodge then continued the work, and produced the *vacuum filing-tube* coherers with automatic tapper-back, which are of acknowledged practical service. It is this varying continuity of contact under the influence of extremely feeble electric stimulus, alternating with mechanical tremor, which, in combination with the mode of producing the waves revealed by Hertz, constitutes the essential and fundamental feature of "wireless telegraphy." There is a curious and widely spread misapprehension about coherers to the effect that, to make a coherer work, the wave must fall upon it. Oliver Lodge has disproved this fallacy. Let the wave fall on a suitable receiver, such as a metallic wire, or, better still, on an arrangement of metal wings resembling a Hertz sender, and the waves set up oscillating currents which may be led by wires (enclosed in metal pipes) to the coherer. The coherer acts apparently by a series of end-impact of the oscillatory current, and does not need to be attacked in the flank by the waves themselves. This interesting method of signalling—already developing in Marconi's hands into a successful practical system, which inevitably will be largely used in light-house and marine work—presents more analogy to optical signals by flash-light than to what is usually understood as electric telegraphy, notwithstanding the fact that an ordinary Morse instrument at one end responds to the movement of a key at the other, or, as arranged by Alexander Muirhead, a siphon recorder responds to an automatic transmitter at about the rate of slow cable telegraphy. But, although no apparent optical apparatus is employed, it remains true that the impulse travels from sender to receiver by essentially the same process as that which enables a flash of magnesium powder to excite a distant eye.

The phenomenon discovered by Zeeman, that a source of radiation is affected by a strong magnetic field in such a way that light of one refrangibility becomes divided usually into three components, two of which are displaced by diffraction analysis on either side of the mean position, and are oppositely polarised to the third or residual constituent, has been examined by many observers in all countries. The phenomenon has been subjected to photography with conspicuously successful results by Professor T. Preston in Dublin, and by Professor Michelson and Dr. Ames and others in America.

It appears that the different lines in the spectrum are differently affected, some of them being tripled with different grades of relative intensity, some doubled, some quadrupled, some sextupled, and some left unchanged. Even the two components of the *D* lines are not similarly influenced. Moreover, whereas the polarisation is usually such as to indicate that motions of a negative ion or electron constitute the source of light, a few lines are stated by the observers at Baltimore, who used what they call the "small" grating of five inches width ruled with 65,000 lines, to be polarised in the reverse way.

Further prosecution of these researches must lead to deeper insight into molecular processes and the mode in which they affect the ether; indeed, already valuable theoretic views have been promulgated by H. A. Lorenz, J. Larmor, and G. F. Fitzgerald, on the lines of the radiation theory of Dr. Johnstone Stoney; and the connection of the new phenomena with the old magnetic rotation of Faraday is under discussion. It is interesting to note that Faraday and a number of more recent experimenters were led by theoretic considerations to look for some such effect; and, though the inadequate means at their disposal did not lead to success, nevertheless a first dim glimpse of the phenomenon was obtained by M. Fleves, of the Royal Observatory at Brussels, in 1885.

It would be improper to pass without at least brief mention the remarkable series of theoretic papers by Dr. J. Larmor, published by the Royal Society, on the relationship between ether and matter. By the time these researches become generally intelligible they may be found to constitute a considerable step towards the further mathematical analysis and interpretation of the physical universe on the lines initiated by Newton.

In the mechanical construction of Röntgen-ray tubes I can record a few advances, the most successful being the adoption of Professor Silvanus P. Thompson's suggestion of using for the anti-cathode a metal of high atomic weight. Osmium and iridium have been used with advantage, and osmium anti-cathode tubes are now a regular article of manufacture. As long ago as June 1896, X-ray tubes with metallic uranium anti-cathodes were made in my own laboratory, and were found to work better than those with platinum. The difficulty of procuring metallic uranium prevented these experiments from being continued. Thorium anti-cathodes have also been tried.

Röntgen has drawn fresh attention to a fact very early observed by English experimenters, that of the non-homogeneity of

the rays and the dependence of their penetrating power on the degree of vacuum; rays generated in high vacua have more penetrative power than when the vacuum is less high. These facts are familiar to all who have exhausted focus tubes on their own pumps. Röntgen suggests a convenient phraseology; he calls a low vacuum tube, which does not emit the highly penetrating rays, a "soft" tube, and a tube in which the exhaustion has been pushed to an extreme degree, in which highly penetrating rays predominate, a "hard" tube. Using a "hard" tube, he took a photograph of a double-barrelled rifle, and showed not only the leaden bullets within the steel barrels, but even the wads and the charges.

Benoit has re-examined the alleged relation between density and opacity to the rays, and finds certain discrepancies. Thus, the opacity of equal thicknessess of palladium and platinum are nearly equal, whilst their densities and atomic weights are very different, those of palladium being about half those of platinum.

At the last meeting of the British Association visitors saw—at the McGill university—Professors Cox and Callendar's apparatus for measuring the velocity of the Röntgen rays. They found it to be certainly greater than 200 kilometres per second. Majorana has made an independent determination, and finds the velocity to be 600 kilometres per second with an inferior limit, certainly of not less than 150 kilometres per second. It may be remembered that J. J. Thomson has found for cathode rays a velocity of more than 10,000 kilometres per second, and it is extremely unlikely that the velocity of Röntgen rays will prove to be less.

Trowbridge has verified the fact, previously announced by Professor S. P. Thompson, that fluor spar, which by prolonged heating has lost its power of luminescing when reheated, regains the power of thermoluminescence when exposed to Röntgen rays. He finds that this restoration is also effected by exposure to the electric glow discharge, but not by exposure to ultra-violet light. The difference is suggestive.

As for the action of Röntgen rays on bacteria, often asserted and often denied, the latest statement by Dr. H. Rieder, of Munich, is to the effect that bacteria are killed by the discharge from "hard" tubes. Whether the observation will lead to results of pathologic importance remains to be seen. The circumstance that the normal retina of the eye is slightly sensitive to the rays is confirmed by Dorn, and by Röntgen himself.

The essential wave-nature of the Röntgen rays appears to be

confirmed by the fact, ascertained by several of our great mathematical physicists, that light of excessively short wave-length would be but slightly absorbed by ordinary materia media, and would not in the ordinary sense be refracted at all. In fact, a theoretic basis for a comprehension of the Röntgen rays had been propounded before the rays were discovered. At the Liverpool meeting of the British Association, several speakers, headed by Sir George Stokes, expressed their conviction that the disturbed electric field caused by the sudden stoppage of the motion of an electrically charged atom yielded the true explanation of the phenomena extraneous to the Crookes high vaccuum tubes—phenomena so excellently elaborated by Lenard and by Röntgen. More recently, Sir George Stokes has restated his "pulse" theory, and fortified it with arguments which have an important bearing on the whole theory of the refraction of light. He still holds to their essentially transverse nature, in spite of the absence of polarisation, an absence once more confirmed by the careful experiments of Dr. L. Graetz. The details of this theory are in process of elaboration by Professor J. J. Thomson.

Meantime, while the general opinion of physicists seems to be settling towards a wave or ether theory for the Röntgen rays, an opposite drift is apparent with respect to the physical nature of the cathode rays; it becomes more and more clear that cathode rays consist of electrified atoms or ions in rapid progressive motion. My idea of a fourth state of matter, propounded in 1881 (*Phil. Trans.*, part 2, 1881, pp. 433-4), and at first opposed at home and abroad, is now becoming accepted. It is supported by Professor J. J. Thomson (*Phil. Mag.* October 1897, p. 312); Dr. Larmor's theory (*Phil. Mag.*, December, 1897, p. 506) likewise involves the idea of an ionic substratum of matter; the view is also confirmed by Zeeman's phenomenon. In Germany—where the term cathode ray was invented almost as a protest against the theory of molecular streams propounded by me at the Sheffield meeting of the British Association in 1879—additional proofs have been produced in favour of the doctrine that the essential fact in the phenomenon is electrified radiant matter.

The speed of these molecular streams has been approximately measured, chiefly by the aid of my own discovery nearly twenty years ago, that their path is curved in a magnetic field, and that they produce phosphorescence where they impinge on an obstacle. The two unknown quantities, the charge and the speed of each atom, are measureable from the amount of curvature and by means of one other independent experiment.

It cannot be said that a complete and conclusive theory of these rays has yet been formulated. It is generally accepted that collisions among particles, especially the violent collisions due to their impact on a massive target placed in their path, give rise to the interesting kind of extremely high frequency radiation discovered by Röntgen. It has, indeed, for some time been known that, whereas a charged body in motion constitutes an electric current, the sudden stoppage, or any violent acceleration of such a body, must cause an alternating electric disturbance, which though so rapidly decaying in intensity as to be practically "dead beat," yet must give rise to an ethereal wave or pulse traveling with the speed of light, but of a length comparable to the size of the body whose sudden change of motion caused the disturbance. The emission of a high-pitched musical sound from the jolting of a dustman's cart (with a spring bell hung on it) has been suggested as an illustration of the way in which the molecules of any solid, not at absolute zero, may possibiy emit such rays.

If the target on to which the electrically charged atoms impinge is so constituted that some of its minute parts can thereby be set into rhythmical vibration, the energy thus absorbed reappears in the form of light, and the body is said to phosphoresce. The efficient action of the phosphorescent target appears to depend as much on its physical and molecular as on its chemical constitution. The best-known phosphori belong to certain well-defined classes, such as the sulphides of the alkaline-earthy metals, and some of the so-called rare earths; but the phosphorescent properties of each of these groups are profoundly modified by an admixture of foreign bodies—witness the effect on the lines in the phosphorescent spectrum of yttrium and samarium produced by traces of calcium or lead. The persistence of the samarium spectrum in presence of overwhelming quantities of other metals, is almost unexampled in spectroscopy; thus one part of samaria can easily be seen when mixed with three million parts of lime.

Without stating it as a general rule, it seems as if with a non-phosphorescing target the energy of molecular impact reappears as pulses so abrupt and irregular that, when resolved, they furnish a copious supply of waves of excessively short wave-length, in fact, the now well-known Röntgen rays. The phosphorescence so excited may last only a small fraction of a second, as with the constituents of yttria, where the duration of the different lines varies between the 0.003 and the 0.0009 second; or it

may linger for hours, as in the case of some of the yttria earths, and especially with the earthy sulphides, where the glow lasts bright enough to be commercially useful. Excessively phosphorescent bodies can be excited by light waves, but most of them require the stimulus of electrical excitement.

It now appears that some bodies, even without special stimulation, are capable of giving out rays closely allied, if not in some cases identical, with those of Professor Röntgen. Uranium and thorium compounds are of this character, and it would almost seem from the important researches of Dr. Russell that this ray-emitting power may be a general property of matter, for he has shown that nearly every substance is capable of affecting the photographic plate if exposed in darkness for sufficient time.

No other source for Röntgen rays but the Crookes tube has yet been discovered, but rays of kindred sorts are recognized. The Becquerel rays emitted by uranium and its compounds, have now found their companions in rays—discovered almost simultaneously by Curie and Schmidt—emitted by thorium and its compounds. The thorium rays affect photographic plates through screens of paper or aluminium, and are absorbed by metals and other dense bodies. They ionise the air, making it an electrical conductor; and they can be refracted and probably reflected, at least diffusively. Unlike uranium rays, they are not polarised by transmission through tourmaline, therefore resembling in this respect the Röntgen rays.

Quite recently M. and Mdme. Curie have announced a discovery which, if confirmed, cannot fail to assist the investigation of this obscure branch of physics. They have brought to notice a new constituent of the uranium mineral pitchblend, which in a 400-fold degree possesses uranium's mysterious power of emitting a form of energy capable of impressing a photographic plate and of discharging electricity by rendering air a conductor. It also appears that the radiant activity of the new body, to which the discoverers have given the name of Polonium, needs neither the excitation of light nor the stimulus of electricty; like uranium, it draws its energy from some constantly regenerating and hitherto unsuspected store, exhaustless in amount.—*British Journal of Photography.*

(*To be continued.*)

THE GREAT METEORIC SHOWER OF NOVEMBER.

H. C. WILSON.

Although the time for the maximum display of this wonderful shower does not come until next year, yet it is probable that the display this year will repay observation better than that of next year, for there will be no Moon to obscure its brilliancy, while next year the Moon will be nearly full. The swarm of meteorites appears to be spread along a great extent of its orbit, so that it takes 6 or more years to pass the Earth's orbit. Small showers were observed in 1895, 1896 and 1897. This year we shall pass so near the densest portion of the swarm that a more remarkable display is likely to be witnessed. In 1832, one year before the great shower of 1833, "on the night of Nov. 11, the workmen engaged in laying the foundation of a new bridge over the river Vienne observed the firmament brilliant with meteors, which at first only amused them, but after some hours the number and splendor of these luminous appearances were so greatly augmented that the people were seized with panics, and so great was their terror that they abandoned their labor and flew to their families, exclaiming that the end of the world had arrived." In 1865 also, one year before the great shower of 1866, according to one description "the heavens were in a blaze with shooting stars" on the morning of Nov. 13. This year the Earth will pass the axis of the swarm at noon November 14, Central Standard time, so that the dense shower is likely to be seen on the opposite side of the Earth, the most favorable places for observation being in China and Japan. There will probably be many meteors, belonging to the shower, visible in America on the mornings of Nov. 14 and Nov. 15, and a few each morning before and after those dates, extending possibly from Nov. 7 to Nov. 20.

In order that any of our readers who desire may be able to record their observations without defacing their star maps, we have prepared the accompanying chart. This contains the stars, down to the 5th magnitude, within 90° of the radiant point of the shower. The positions of the stars are laid down in such a way that all great circles passing through the radiant in Leo are projected as straight lines, without being foreshortened. All paths of the meteors belonging to the Leonid shower, should they describe exact arcs of great circles across the sky, may be drawn as straight lines upon this chart, and, when extended backward, will indicate the position of the radiant by their common inter-

section. Previous determinations place the radiant within the sickle-shaped group of stars in the western portion of the constellation Leo, near the center of the chart. We have purposely left its position undesignated upon the chart, so that observers make their own determinations independently.

We shall be glad to furnish, upon application, extra copies of the chart to those who will agree to use them and send us copies of their records. A separate copy of the chart should be used on each night. The paths of as many meteors as the observer can determine accurately (and only that many) should be drawn with a soft pencil upon the chart, the heaviness of the line indicating its brightness and an arrowhead its direction, the ends of the path being located as closely as possible with reference to the neighboring stars. A reference number may be written at the arrow point at the end of the path and notes kept with reference to the peculiarities of the meteor, time of appearance, duration, etc., upon separate sheet or record book. The observer should be seated at a table, with the chart tacked down to a smooth board, with a straight edge ruler and pencils at hand, and either a dark lantern or a lamp enclosed in a box which will keep off the wind and protect the observers eye from the light, except where it necessarily falls upon the chart. The position should be such as to command an unobstructed view of the eastern half of the heavens at midnight and the southern half, as well as the region overhead, in the morning. The radiant rises at about 11^h P. M. in our latitude on Nov. 14, and will be on the meridian at about 6:30 A. M.

A number of observers provided with cameras driven by clockwork will employ the photographic method for registering the paths of meteors, but these can cover only limited areas of the sky and only the brightest meteors will produce any impressions upon the photographic plate. There is therefore abundant reason for using the old eye and hand method.

A number of valuable suggestions as to what phenomena should be observed and how the work should be done, are given in an extended article by Mr. W. F. Denning, the veteran meteor observer, contained in several numbers of *The Observatory* for 1897. We quote the following:

"In this class of observation practice is indispensable, and not much really good work can be accomplished until the observer has made himself familiar with its requirements. Our previous knowledge in this department has been gained by persistent effort and careful observation, which, however, have been far from absolutely accurate, and could not be otherwise from the nature of the performance. The paths of meteors, as recorded, are but hurried and often rough eye-estimates

of position, consequently a large probable error must naturally attend them. These, however, can be reduced to very moderate limits by habitual training, and especially in cases where the observer possesses aptitude for this kind of work. There is (and obviously must be, owing to the great distinctions existing in individuals as to their relative capacity for a labor which requires a good eye, untiring patience, quickness of conception, and a sound judgment) a great difference as to the probable error in various cases, for one person in fixing radiants may show a mean error of 6° or 7°, while another may be well within 2°. Unfortunately there is no school for educating aspirants to proficiency and fame in this field, nor is there any tribunal where observers may come up for trial and judgment as to the accuracy of their results. But the degree of exactness attained by any one may be pretty well gauged by comparing the materials he has gathered with the average of the best results obtained by other observers.

The observation of a brilliant shower of streak-leaving meteors, like the Leonids, is much less difficult, complicated, and perplexing than that entailed in the general investigation of minor streams. The paths of Leonids can sometimes be registered very precisely by perfect novices in this particular work, as the streaks of prominent meteors remain some seconds, if not some minutes, and their exact location amid neighboring stars can be marked on a globe or map by any one acquainted with the constellations. It must be done, however, in each case, as quickly as possible after the nucleus itself is spent, for the streak begins to drift immediately after the moment of its first projection, and it is only at this time that it correctly represents the path pursued by the nucleus.

As to the observations necessary to be made, they may be described as manifold. It is not sufficient to stand and merely count the numbers visible at certain intervals, and jot down a few notes of the brighter objects. The phenomenon requires critical watching with regard to certain important features, and among these the following may be instanced:

1. The exact time of maximum abundance.
2. The number of meteors visible per minute at maximum.
3. The position of the centre of radiation.
4. The diameter of the area of the radiant, if diffuse.
5. The duration of the shower's chief activity.
6. The whole duration of its visibility (from about Nov. 7 to 20).
7. The relative magnitudes of the meteors.
8. The durations of their visible flights.
9. The colors of the meteors and of their streaks.
10. The durations of the streaks and extent and direction of their drift. In the case of very bright streaks enduring a long time a series of positions for the central part should be taken say at intervals of 2 or 3 minutes.
11. The apparent paths of the brighter meteors. Many of these will be sure to be seen at several stations, and if properly recorded the data will enable their real paths to be derived.
12. The places of apparition of stationary meteors.
13. The number of meteors proceeding from other showers. These will probably not amount to more than 10 or 12 per hour, and need not be considered during a really brilliant return of the Leonids. During a feeble display, however, meteors diverging from the minor systems should be carefully separated from the Leonids or the real strength of the latter will be exaggerated.
14. The shape of the nuclei and their apparent diameters in the case of bolides.
15. Instances of curved paths, broken streaks, and other visible peculiarities.

After the disruption of large meteors the observer should listen for some minutes with the idea of noticing any audible detonation should it be possible.

Of course more than two observers must be employed to thoroughly record

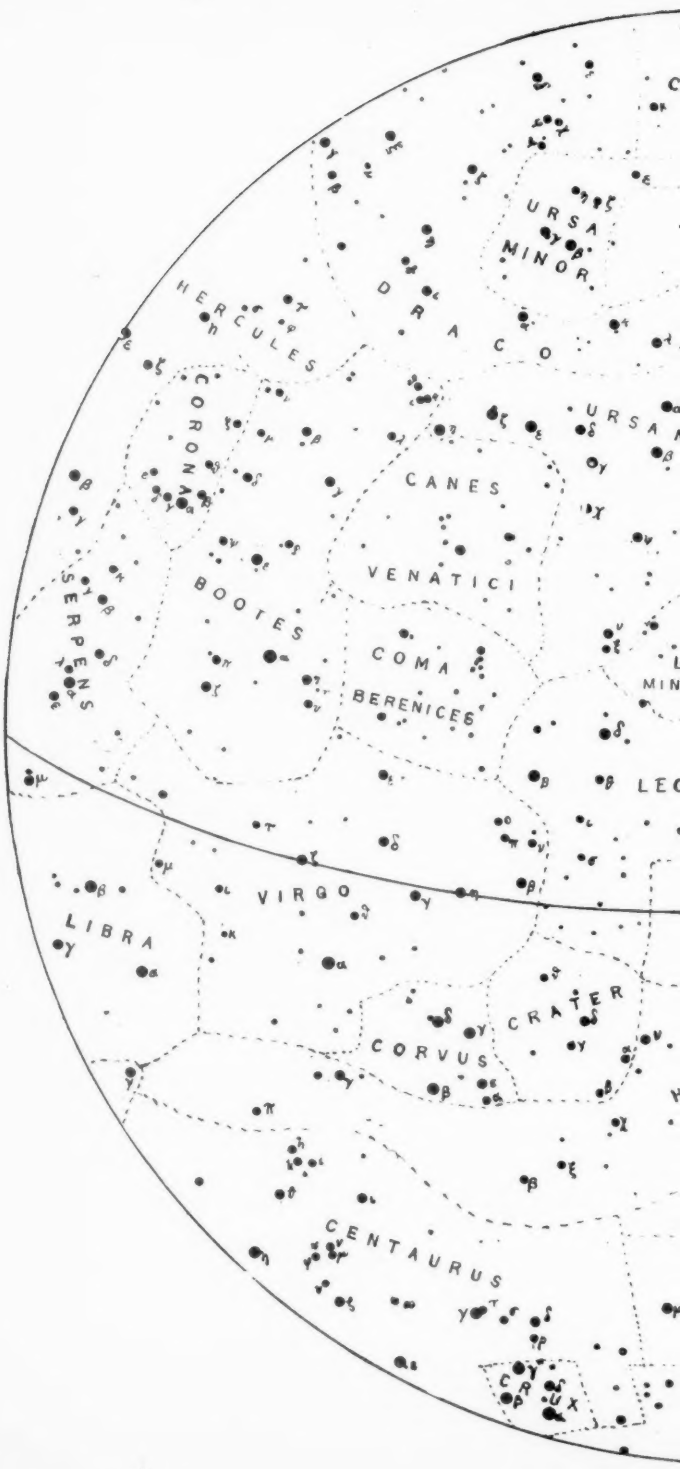
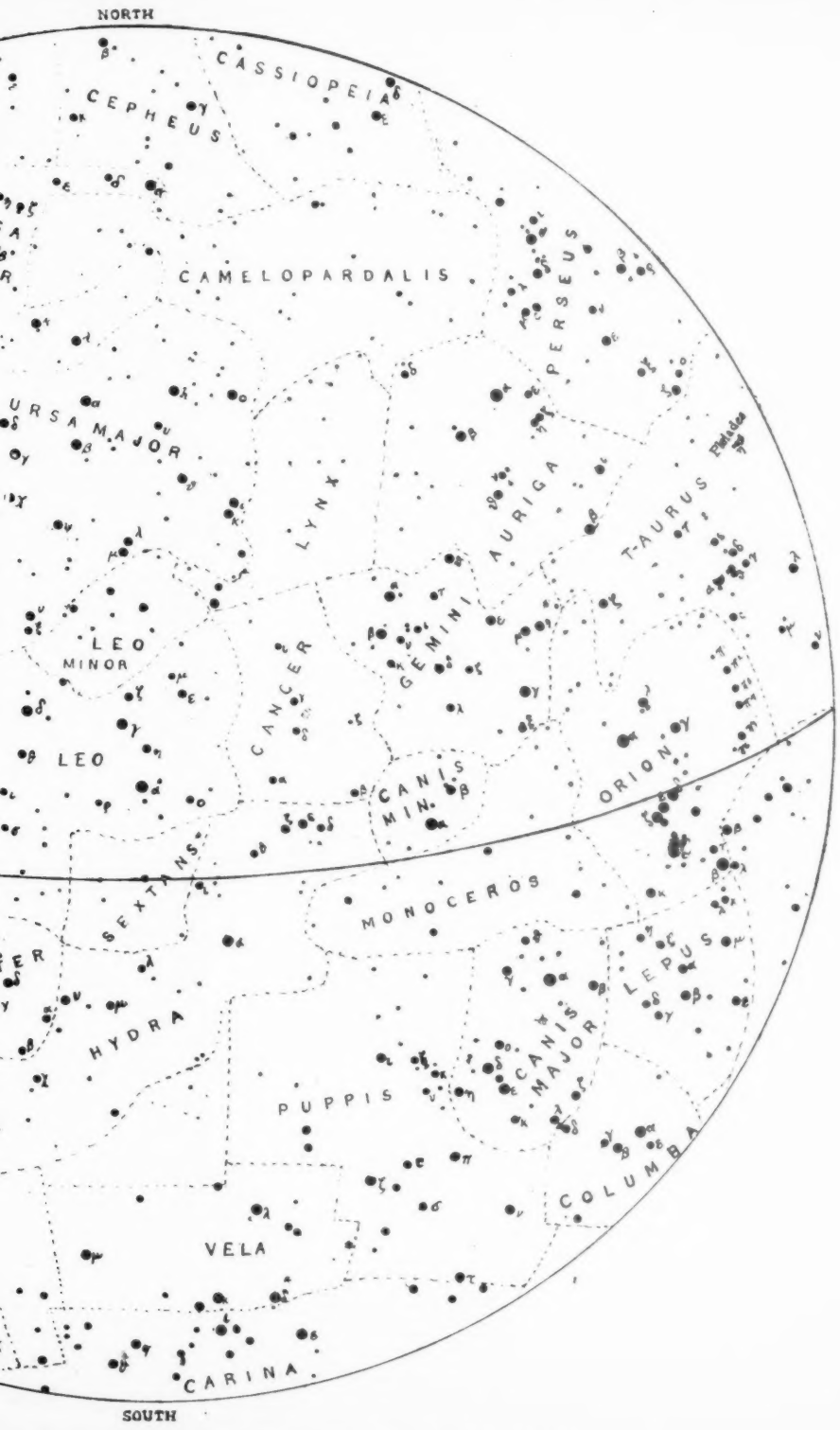


CHART FOR RECORDING PATHS O

PLATE XIII.



PATHS OF THE LEONID METEORS, NOV. 14–15, 1898

the characteristics of a meteoric display. One should count the numbers visible during, say, every successive period of 5 minutes, and record the totals, so that the rate of increase, time of max., rate of decrease, and the duration of great activity may be severally determined. Another will register the paths of individual meteors, determine the place of the radiant at, say, half-hourly intervals, while a third will derive the relative magnitudes by watching one particular quarter of the heavens and recording the various magnitudes of all the meteors which appear there. By separating the materials collected in this way into half-hourly intervals, it might be seen whether any variation occurred during the rise, height, and fall of the display, or whether the altitude of the radiant exercised any influence upon the apparent brilliancy of the meteors.

One observer, in relying upon his own exertions, will perhaps do best by counting the meteors during every alternate five minutes, and recording paths and other details in the intervals. Should meteors be too numerous for exact enumeration, the number ought to be carefully estimated. Or by watching a very contracted region of the sky (which might be done by standing far back from an open window, or by looking through an empty telescope-tube, or by some other device which the observer might readily arrange for himself), the number of meteors appearing in the field might be counted; and the diameter and altitude of the space under view being known, as well as the average length of the paths, a computation might easily be made as to the number of meteors which appeared in the whole sky."

VARIABLE STARS IN CLUSTERS

EDWARD C. PICKERING.

The discovery, by Professor S. I. Bailey, of the presence of large numbers of variable stars in certain globular clusters has already been announced in Circulars Nos. 2 and 18. A systematic search for such variable stars has been made by Professor Bailey and has led to the results given below. In the following table the first column gives the number in the New General Catalogue of Dreyer; the second, the Messier number, or in certain cases some other designation; the third and fourth columns the position for 1900; the fifth column the approximate number of stars examined; the sixth, the number of plates used in the examination. In the case of certain clusters later investigations have included more plates. The seventh column gives the area, always a circle having for its centre the centre of the cluster, included in the examination. The eighth column gives the number of variable stars found; the ninth, the maximum distance of any variable from the centre of the cluster. In N. G. C. 7078 this distance is given as 7′, since a circle having a radius of 7′ includes 50 variables. One variable, perhaps not related to the others, is found at a distauce of 10′. The tenth column gives the area of a circle of sufficient radius to include all the variables. The eleventh

column gives the proportion of variables to the whole number of stars examined; the twelfth, the number of stars to one variable.

As will be seen by reference to the table, the whole number of stars examined is 19,050, of which 509 are variable. This amounts to one variable in 37 stars or nearly 3 per cent. It does not follow however that clusters in general contain more variable stars than occur elsewhere, for, if we except the four clusters, ω Centauri, Messier 3, Messier 5, and Messier 15, which together contain 393 variables, an average of 7 per cent, the remaining 19 clusters have 116 variables among 13,350 stars, or less than one per cent. There is a very striking difference between the results obtained in clusters equally rich in stars, as for example, between Messier 13, the great cluster in Hercules, where an examination of 1,000 stars shows two variables, one in 500; and Messier 3, where among 900 stars, 132 are variable, one in 7. A common plane of revolution, orbital or axial, of the different systems or individuals of star clusters, and the relation of that plane to the line of sight, might provisionally be suggested as a possible explanation.

VARIABLE STARS IN CLUSTERS.

Designation.		Position, 1900. R. A.		Position, 1900. Decl.		No. stars examined.	No. plates examined.	Area examined.	No. variables found.	Maximum distance.	Area of variables.	Proportion of variables.	No. of stars to one var.
		h	*m*	°	′			Sq. Min.		′	Sq. Min.		
104	47 Tucanae	0	19.6	— 72	28	2000	10	1257	6	6	113	.003	333
362		0	58.9	— 71	33	675	10	314	14	9	254	.021	48
869		2	12.0	+ 56	41								
884		2	15.4	+ 56	39	1630	10	10800	1	——	——	.001	1050
1904	Messier 79	5	20.1	— 24	37	200	6	79	5	3.5	38	.025	40
3293		10	29.6	— 57	46	724	10	314	0	——	——	.000	——
4755	κ Crucis	12	47.7	— 59	48	535	10	314	0	——	——	.000	——
5139	ω Centauri	13	20.8	— 46	47	3000	10	1257	125	22	1521	.042	24
5272	Messier 3	13	37.6	+ 28	53	900	10	1257	132	17	908	.147	7
5904	Messier 5	15	13.5	+ 2	27	900	10	1257	85	17	908	.094	11
5986		15	39.5	— 37	26	289	12	314	1	1.7	——	.003	289
6093	Messier 80	16	11.1	— 22	44	145	5	79	2	2.5	20	.014	72
6205	Messier 13	16	38.1	+ 36	39	1000	10	177	2	1.3	5	.002	500
6266	Messier 62	16	54.9	— 29	58	900	10	218	26	8	201	.027	37
6397		17	32.5	— 53	37	487	5	218	2	7.5	177	.004	244
6626	Messier 28	18	18.4	— 24	55	900	9	314	0	7	154	.010	100
6656	Messier 22	18	30.3	— 23	59	1550	10	218	10	8	201	.010	97
6723		18	52.8	— 36	46	900	6	314	16	4.5	64	.018	56
6752		19	2.0	— 60	8	600	8	218	1	4	——	.002	600
6809	Messier 55	19	33.7	— 31	10	440	6	218	2	5	79	.005	220
7078	Messier 15	21	25.2	+ 11	44	900	10	1257	51	7	154	.057	18
7089	Messier 2	21	28.3	— 1	16	600	10	218	10	4	50	.017	60
7099	Messier 30	21	34.7	— 23	38	275	10	218	3	2.5	20	.011	92
						19050		20830	509		4867		

The periods and light curves of several variables in other clusters have been determined, but the study of those in ω Centauri

is well advanced. This cluster may be called the finest in the sky. It lies just within the border of the Milky Way. There are no bright stars near. To the naked eye it appears as a hazy star of the fourth magnitude. It has a diameter of about 40′. The brightest individual stars in this region are between the eighth and ninth magnitude. Over 6000 stars have been counted on one of the photographs, and the whole number is much greater. Only about 3000, however, are sufficiently bright and well separated to serve for comparison in the discovery of variables. Of these 3000, 125 are variable. 150 photographs of the cluster have been taken with the 13″ telescope and already 10,000 measures have been obtained, about half of which have been made by Miss E. F. Leland.

Although the results are at present provisional, it is not probable that the final results of the discussion will materially alter the conclusions. Of the 106 variables in ω Centauri whose periods have been determined, 98 have periods less than 24^h. The longest period is that of No. 2, 475^d, the shortest that of No. 91, $6^h\ 11^m$. Three have periods less than 7^h. Of the eight having periods of more than 24^h, two have periods between one and two days, two between two and three days, one of 4 days, one of 15 days, one of 150 days, and one of 475 days.

The largest range in variation is about five magnitudes, and no star has been included whose light changes do not amount to half a magnitude.

The light curves of the 98 stars whose periods are less than 24 hours may be divided into four classes. The first is well represented by No. 74. The period of this star is $12^h\ 4^m.3$, and the range in brightness, two magnitudes. Probably the change in brightness is continuous. The increase of light is very rapid, occupying not more than one-fifth of the whole period. In some cases, possibly in this star, the light remains constant for a short time at minimum. In most cases, however, the change in brightness seems to be continuous. The simple type shown by No. 74 is more prevalent in this cluster than any other. There are, nevertheless, several stars, as No. 7, where there is a more or less well marked secondary maximum. The period of this star is $2^d\ 11^h\ 51^m$, and the range in brightness, one and a half magnitudes. The light curve is similar to that of well known short-period variables, as δ Cephei and η Aquilæ. Another class may be represented by No. 126, in which the range is less than a magnitude, and the times of increase and decrease are about equal. The period is $8^h\ 12^m.3$. No. 24 may perhaps be referred to as a

fourth type. The range is about seven tenths of a magnitude, and the period is $11^h\ 5^m.7$. Apparently about 65 per cent of the whole period is occupied by the increase of the light. This very slow rate of increase is especially striking from the fact that in many cases in this cluster the increase is extremely rapid, probably not more than ten per cent of the whole period. In one case, No. 45, having a period of $14^h\ 8^m$, the rise from minimum to maximum, a change of two magnitudes, takes place in about one hour and in certain cases, chiefly owing to the necessary duration of a photographic exposure, there is no proof at present that the rise is not much more rapid.

The marked regularity in the period of these stars is worthy of attention. Several have been studied during more than a thousand, and one during more than five thousand periods, without irregularities manifesting themselves.

A few words may be added in regard to the kind of clusters in which variables have been found. Up to the present time they have not been found in any except dense globular clusters, of which Messier 3, Messier 5, and the great cluster in Hercules may be taken as examples. The number of such clusters within the reach of ordinary instruments is not great. Of the clusters given in the table N. G. C. 104, 362, 5139, 5272, 5904, 6093, 6205, 6266, 6626, 7078, and 7089 may be described as highly condensed; 1904, 5986, 6397, 6656, 6723, 6752, 6809 and 7099 as moderately condensed; and 3293 and 4755 as open clusters. 869 and 884, the clusters in the Sword-handle of Perseus are little more than regions relatively rich in stars.

The first group of 11 highly condensed clusters having a total of 11980 stars has 462 variables, or one in 26. The second group of 8 moderately condensed clusters has 46 variables among 4741 stars, one in 103. The two open clusters furnished no variables, and the region of three square degrees around N. G. C. 869 and 884, only one.

Thus far the only regions which are found to be especially rich in variable stars are condensed clusters, but even here only in relatively few cases. These dense clusters are commonly called globular, and many of them are such. In some cases however, as ω Centauri, the form is somewhat elliptical.

N. G. C. 6266 is the most striking example of a highly condensed cluster which is irregular in form. This irregularity is intensified in the distribution of the variables. The cluster is much compressed on the south side. For a distance of 1′ from the centre the distribution of the stars seems to be about equal, but if a

line be drawn east and west through the centre, and the stars within 1′ of this line are omitted, there are 214 stars south, and 354 stars north, within 4′ of the central line. In this cluster are 26 variables, of which 19 are north of the central line and 7 south. Excluding those within 70″, there are 15 north and only 1 south.

HARVARD COLLEGE OBSERVATORY,
Circular No. 33.
September 17, 1898.

ON THE LATEST ADVANCES IN KNOWLEDGE OF THE MOTION OF THE POLE.

S. C. CHANDLER.

FOR POPULAR ASTRONOMY.

In connection with an investigation of revised elements of the polar motion I recently gave (*A. J.* 446) diagrams for comparison of its observed course, between 1890.0 and 1897.5, with that predicted by the geometrical theory deduced several years since from the observations from 1825 to 1893. I have thought that it might be of interest to the readers of POPULAR ASTRONOMY to present here new diagrams representing the track pursued according to the present revised elements, extending through the next seven-year cycle. These new curves are laid down by rectangular coördinates computed from the revised elements given in the place quoted, namely:—

$$x = r_1 \sin (t - T_1)\, 0 + 0''.095 \sin (\odot - 308°)$$
$$y = r_1 \cos (t - T_1)\, 0 + 0\ .110 \cos (\odot - 3°)$$

where

$$T = 2412646 + 427\ 0 - 0.08\ E^2$$
$$0 = 0°.843 + 0°.000316\ E$$
$$r_1 = 0''.125 + 0''.05 \sin (2414363 - t)\ 0°.015$$

E being the number of 427^d periods elapsed since the principal epoch adopted, Julian Day 2412646 = 1893 July 1. Dots are placed on the curve at intervals of tenths of years, the beginning of each year being marked by the date and the middle of the year by the small figure 5. The center of the chart is the pole of rotation; the meridan of Greenwich is that indicated by ″.00 at the top, and the meridian 90° west of Greenwich by ″.00 at the right. This will suffice for all necessary explanation.

The diagrams present several instructive features. One that strikes the notice at first glance is that for the cycle 1897-1904 the gyrations are confined to a smaller region than those for

1890-97. Those for 1890-97 may be comprised in a rectangle 0″.59 by 0″.41, while those for 1897-1904 are covered by a rectangle 0″.52 by 0″.32; thus nearly one-tenth of a second smaller in each dimension. The reason for this is that the radius of the circular 427^d component is at present gradually diminishing. This fact was brought to light by a study of the observations from 1825-90 (*A. J.* 322) where it was remarked, "It will be noted that the amplitude of the 428^d term will decrease during the next few years by an amount which ought to be appreciable from exact observation." This forecast has been fully confirmed by the observations since made, the discussion of which shows that the diminution has actually been from about 0″.18 to about 0″.12 during the interval 1890-97, thus even slightly more pronounced than that prescribed by the theory, which further indicates that the decrease will continue for many years longer. While on this topic it is apposite to mention that there appears to be a misinterpretation of fact in connection with it in Albrecht's report of the *Centralbureau* of the International Geodetic Survey (1898). On page 9, after remarking that the curve of 1897 is decidedly smaller than that of 1890, the author draws the inference, from the fact that the curve does not return exactly into itself in seven years, that this would demonstrate "the impossibility of exhaustively representing the course of the pole by two terms, of 12 and 14 months." Such a proposition is true only on the assumption that the radii are invariable. That this is not so with regard to the 427^d term was long ago shown by satisfactory evidence, independently of the observations of recent years which now abundantly confirm it, and the fact was incorporated into the numerical theory in 1894. It is also curious that this recent diminution of amplitude in this component has been entirely overlooked by Bakhuyzen in a discussion of this general subject just published, in which he fully confirms the theory in other respects. Thus he gets the elements of the annual ellipse given below under *B*, by the side of which are placed those that I originally obtained five years ago under *C* and those of my revised elements under C_1.

		B	*C*	C_1
Pole passes major axis,	*T*	Mar. 29	Apr. 5	Apr. 7
Major axis east of Greenwich,	ω	19°	45°	39°
Length of major axis,	*a*	0″.24	0″.30	0″.275
Length of minor axis,	*b*	0 .12	0 .08	0 .085

The most striking difference here, that in ω, may be attributed partly to his erroneous assumption of 431^d.1 as the period of the circular component, partly to differences in the observed curves used as a basis of the investigations. If his scrutiny had

been closer, he could not have failed to perceive the contraction in the curve of which we are speaking, and which even Albrecht recognizes. It is singular that in spite of this he should have drawn the conclusion, on insufficient grounds, on page (47) of his paper (*Proc. Amsterdam Academy*, 1898) that there is no evidence of such variation.

It is an unfortunate consequence of this gradual drawing in of the convolutions of the curve, caused by this diminution of one of its component motions, that the latitude-variations during immediately coming years will be on a distinctly smaller scale than hitherto, and therefore less easy to observe. Thus by the right hand diagram it will be seen that from the middle of 1899 to the middle of 1903, a space of nearly four years, the excursions of the pole of figure from its mean position will rarely be so great as 0″.15, the average amount being under 0″.10; while for two years, from 1900.5 to 1902.5, its departures will be practically confined within a tenth of a second from the pole of rotation, the average distance being only 0″.07.

Another interesting and unique feature is that between the two nodes near the beginning of 1901 and 1902, the pole will describe a small circle in a retrograde direction, that is from east to west, or in a directly opposite sense to its usual behavior.

It should be observed that the track of the pole predicted by the theory is subjected to a slight uncertainty—although not enough to disturb its general character as depicted on the chart—arising from the effects of progressive changes in the annual ellipse, such as I have indicated in my investigations as probably taking place, without being able to define them sufficiently to make it safe to incorporate them in the numerical theory, which it is of course desirable to keep clear of unverified hypotheses. In the article A. J. 446, it is shown that there is some indication that the line of apsides may be at present slowly retrograding. That is, the major axis, which lay about 45° East of Greenwich in 1890, was only about, say, 30° east in 1896. Also the longitude of the epoch, L, seemed apparently larger towards the end of this interval. If the latter fact be confirmed, it can of course be concluded that the annual period is not at present exactly a year, but slightly longer, say about 367 days. This apparent evidence of variation in the annual period is curiously in accord with the testimony to the same effect afforded by the observations from 1825 to 1890, which I had pointed out four years ago and indeed embodied in the empirical formula given in *A. J.* 322,

$$G = 317° - 44° \cos (t - 1865.25)\ 5°.48$$

which gives as the variable length of the annual period

$$365^d.25 + 4^d.21 \sin (t - 1865.25)\ 5°.48$$

whose value for 1893.5 is 367.0 days. Thus the older observations point in the same direction as the recent ones. We must patiently await a few more years' observation for confirmation. But we may regard the fact as extremely probable, and should therefore not be surprised if some deflection from the computed curves here given, which are based on a fixed ellipse, gradually manifests itself. If these and possibly other changes are in operation the problem of their determination is an exceedingly difficult and delicate one; yet we may hope that it will become completely determinate when the phenomena of the cycle from 1897-1904 have been unfolded by observation. Meanwhile it is gratifying that the advance in our knowledge of these mysterious movements of the Earth's axis is so rapid and so sure, and that our grasp of their geometrical laws, derived almost entirely from the observations made anterior to the discovery of the existence of these movements, is only confirmed and strengthened by the record of the past seven years; during which the phenomenon has taken its place in the body of approved astronomical knowledge so firmly that even the coyest conservatism is getting wonted to it, and no longer eyes it askant.

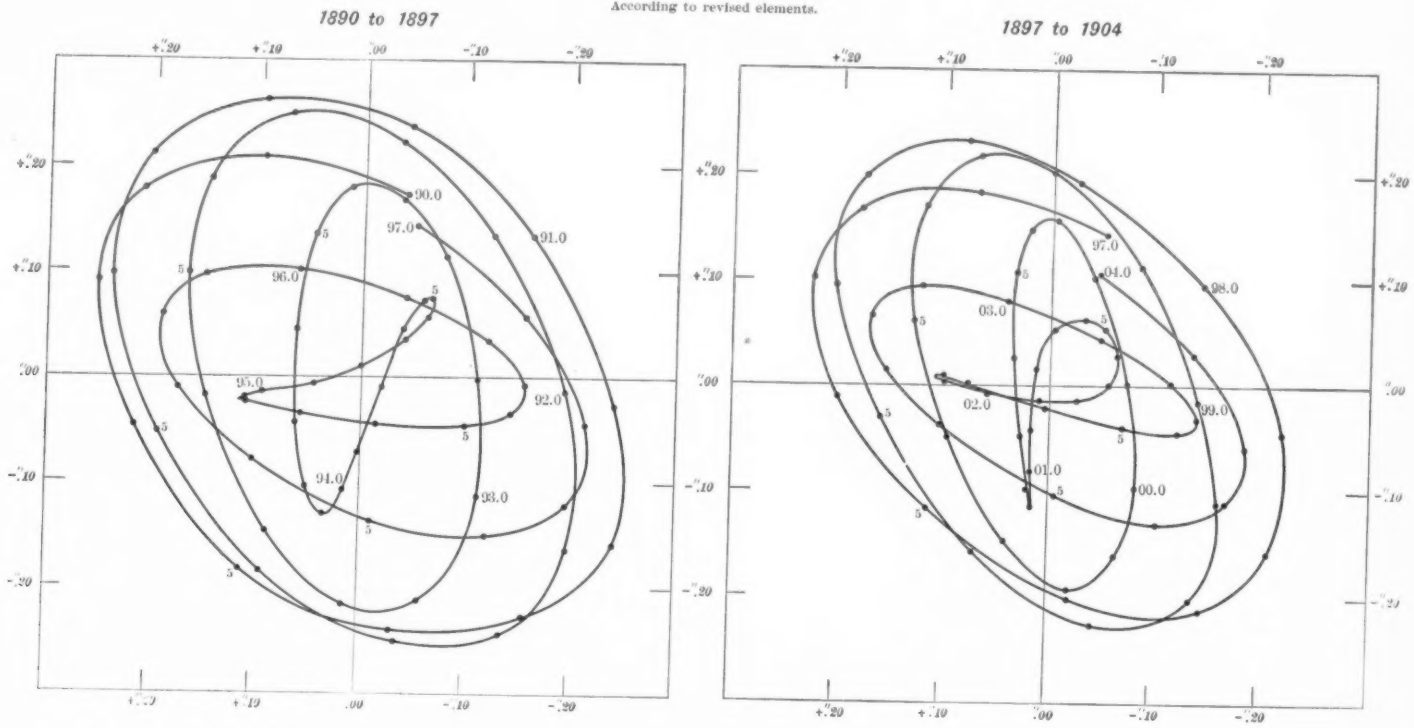
The diagrams here given may of course be utilized for getting very approximate values of the variations of latitude for any station, in the same way as was indicated in *A. J.* 329 for the diagram there given, and which was reproduced in POPULAR ASTRONOMY for Nov., 1895. For convenience I will repeat the directions. Draw a line from the center of the chart towards the longitude of the station. A perpendicular let fall upon this line from any point of the curve will cut the line at a distance from the center of the chart equal to the variation of latitude $(\varphi - \varphi_0)$ on that date for that station, to be taken positive if the perpendicular falls beyond the center, negative if it falls between the center and the station. Perpendiculars tangent to the curve will give dates and amplitudes of maxima and minima of the latitude-variation.

I take this opportunity to make the following explanation, tc avoid possible misconstruction. In the investigation in *A. J.* 446 the results of the valuable series of observations, since 1893, by Mr. George A. Hill, at the Washington Observatory, combining the work of the Prime Vertical Transit and a small Zenith Telescope, were not incorporated. This omission was not intended

PLATE XIV.

Path of the Pole

According to revised elements.



in the slightest degree to derogate from the character or value of this series, but was due to the fact that the materials for my investigation were gathered, and the computations made, last spring, when it was not intended to publish the paper until the results of observation for the current year were at hand. Mr. Hill's series required, and I felt would repay, an intimate examination—which could not be made effectively until the details of the latter portion of it should be printed—concerning the nature of certain anomalies, no greater, indeed, than other series of prime vertical observations of the best class seem to be occasionally affected with, but which merit searching attention. Moreover, I had learned that Mr. Hill himself proposed to make a discussion of these observations in behalf of a determination of the aberration-constant, and it seemed desirable to await this discussion, which could not fail to be of great help in elucidating the points in question.

It was only very recently that I concluded to print the paper this year, and this had to be done as it stood, during my summer sojourn in the country, without facilities for perfecting it in this and other respects.

Mr. Hill's undertaking is most hopeful and interesting and decidedly should be persevered in. I have not the slightest doubt that his zeal, industry and skill will have the reward of useful result that they so fully deserve and that all astrohomers must heartily desire for him.

COMET *h* 1898 (Perrine.)

C. D. PERRINE.

FOR POPULAR ASTRONOMY.

From the Mount Hamilton observations of September 12, 17 and 22, I have obtained the following system of parabolic elements:

T	1898 October 20.53478 Gr. M. T.			
	°	′	″	
ω	162	26	8.3	} Ecliptic and Mean Equinox of 1898.0
Ω	34	55	37.5	
i	28	51	27.2	
$\log q$	9.622688			

RESIDUALS FOR THE MIDDLE PLACE.

Obs.—Comp.	$\Delta\lambda' \cos\beta'$	$+0''.4$
	$\Delta\beta'$	$-1\ .0$

CONSTANTS FOR THE EQUATOR OF 1898.0

$$x = r\,[9.982752]\ \sin\,(283\ 53\ 7.9 + v)$$
$$y = r\,[9.846710]\ \sin\,(210\ 48\ 53.4 + v)$$
$$z = r\,[9.882722]\ \sin\,(179\ 48\ 12.1 + v)$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1898	True α	True δ	log Δ	Br.
	h m s	° ′		
Sept. 30.5	11 26 39	+ 18 0.3	0.142	2.96
Oct. 2.5	39 38	15 53.7		
4.5	11 52 38	13 40.2	0.138	3.70
6.5	12 5 37	11 19.7		
8.5	18 36	8 52.8	0.138	4.68
10.5	31 35	6 19.9		
12.5	44 35	3 41.4	0.140	5.76
14.5	12 57 37	+ 0 58.7		
16.5	13 10 41	− 1 47.6	0.144	6.66
18.5	23 49	4 35.9		
20.5	37 1	7 24.6	0.149	6.93
22.5	13 50 17	10 11.9		
24.5	14 3 38	12 56.0	0.154	6.37
26.5	17 3	15 34.9		
28.5	30 33	18 7.7	0.159	5.28
30.5	44 7	20 32.9		
Nov. 1.5	14 57 46	22 49.7	0.166	4.13
3.5	15 11 30	24 57.7		
5.5	25 18	26 56.8	0.173	3.16
7.5	39 9	28 46.5		
9.5	15 53 3	30 27.0	0.183	2.41
11.5	16 6 56	31 58.0		
13.5	20 49	33 19.9	0.194	1.85
15.5	34 38	34 33.9		
17.5	16 48 22	35 37.5	0.210	1.42
19.5	17 1 57	36 33.9		
21.5	15 21	37 22.4	0.221	1.13
23.5	28 32	38 3.5		
25.5	41 29	38 37.8	0.236	0.89
27.5	17 54 9	39 5.6		
29.5	18 6 30	− 39 27.5	0.252	0.71

Brightness on September 13 = 1.0

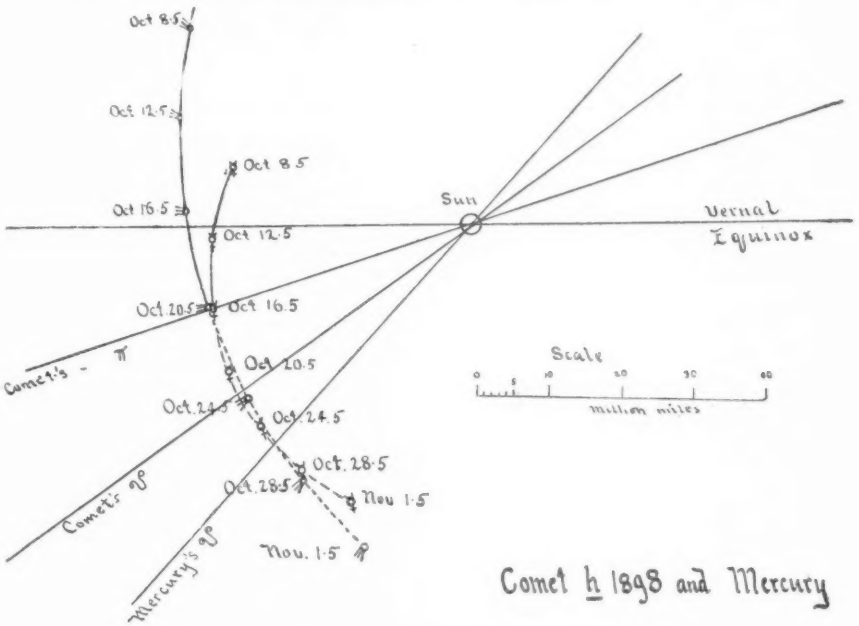
From the above ephemeris it will be seen that the comet is in conjunction with the Sun on October 22 after which it becomes an evening object, but as it is moving rapidly south it will not likely be seen again by northern observers. It should however, be sufficiently far east and south of the Sun by November 1 to be seen from southern stations.

The comet has increased considerably in brightness and is now just visible to the naked eye. The nucleus which has developed within the past week is almost stellar in its sharpness and is of the 9th magnitude. The tail has also become much brighter and more distinct.

The head of the comet is about 4′ in diameter or 150,000 miles. The tail can be traced for ¼° with the 12-inch telescope using a power of 150. This is an actual length of 600,000 miles. The

extent of the coma and the length of tail are probably much greater than can be seen under the usual conditions.

The perihelion distance of the comet is exactly the same as the planet Mercury's distance from the Sun in that part of its orbit and as the descending nodes are within about 12° of each other, it is possible for Mercury and the comet to be quite near each other. It happens in the present case that Mercury is in that part of its orbit at the same time as the comet, although a little in advance of the position which would cause the closest approach. On October 28 both bodies have the same longitude and their distance from the Sun are almost exactly the same, but owing to other conditions their latitudes are 8½° different. Nevertheless they are within six millions of miles of each other and for a week or more their distance is not much greater.



Comet h 1898 and Mercury

It will be interesting to note what appearance the comet would have as seen from Mercury. The conditions will be favorable as the comet will be practically in opposition to the Sun. At their nearest approach the head of the comet will be 1½° in diameter and over 150 times as bright as it was as seen from the Earth on September 27 when it was just visible to the naked eye. This in-

crease of brightness would cause it to appear brighter than an average first magnitude star. The tail would be 5° long at least, and probably two or three times this length, should it show the customary increase of action as it nears the Sun.

Its close approach to Mercury will cause considerable perturbation by the latter, but just what the effect will be cannot be foretold from our present knowledge of the comet's orbit.

LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,
1898, September 28.

ASTRONOMY IN SOUTHERN CALIFORNIA.

LEWIS SWIFT.

FOR POPULAR ASTRONOMY.

Until comparatively a recent date no one suspected that California, especially the southern part—so near as it is to the mighty Pacific—possessed any advantage for astronomical observations over its sister states. Those who came to search for treasure in the earth, instead of the heavens, gave no heed to its climatic conditions. At length, when a few astronomers ventured so far from their labors across hundreds of miles of desert, visited the then Territory, and saw the vast number of cloudless nights, especially in the mountains, where fogs seldom reach, it at once occurred to them that this must be the astronomers' paradise, and so it has proved to be.

The Lowe Observatory, over which I have charge, is as yet the only one in southern California. It is the fartherest south of any in the world north of the equator, except one in Mexico, which gives it great advantage over the northern ones. It is situated on a spur of the Sierra Madre mountains, five miles from Pasadena, fifteen miles from Los Angeles and thirty-five miles from the Pacific Ocean, and, about 2700 feet above it in latitude 34° 20′ north.

Its instruments are the same as did service at the Warner Observatory at Rochester, N. Y. A brief recital of a few facts regarding the Observatory and the work accomplished since it was built in the latter part of 1894, may not be wholly devoid of interest to the astronomical section of this association.*

It is outside of my present purpose to go deeply into details of

* The article was read before the American Association for the Advancement of Science at its Boston meeting in August, 1898.

what has been accomplished in a little over three years, nor the many disadvantages under which I have labored all alone. The Observatory is a private affair, built as an attraction to this celebrated mountain resort, and consequently it is open to visitors at all reasonable hours, and of course greatly to the interference of the director's work. It possesses one advantage over a large majority of the observatories of the world, the absence of electric street lights, which nearly stopped my nebular work in Rochester. Though the electric lights in Pasadena and Los Angeles are plainly visible, they are too distant to prevent observations of that faintest of all faint objects, the Gegenschein. My work has been the same as was pursued in Rochester; the discovery of comets and nebulæ, which to prosecute successfully requires a large telescope, the best of seeing, a trained eye, a suitable eye piece, and last, but not least, a love for the work. Fortunately since my removal here, I have been in possession of them all. I find a majority of Herschel's Class III very easy objects. I often find a Nova in the same field with some one of his, which considering the size of his telescope is surprising he failed to see.

The result of my work here has been the discovery of over 300 nebulæ. 242 have recently been published entire in the *Astronomische Nachrichten*, reduced to the epoch of 1900, and five comets including the naked eye and opera glass comets seen simultaneously about one degree east of the Sun. Also one comet discovered by my son Edward D., a periodic of about 6 years, which with some probability, is identical with the lost comet of Di Vico. One of mine is also a Jupiter comet, whose elements closely resemble those of Lexell's comet lost for 125 years.

Whether the two comets discovered close to the Sun and to each other, through an atmosphere dense with smoke, were really two distinct comets, or, only one with a companion, will never be known. They were seen by a dozen people on the mountain and through three different opera glasses. Their intrinsic brightness to be visible, one of them conspicuously so, to the naked eye, through smoke from forest fires so dense as to allow the setting Sun to be looked at without discomfort, must have been very great. It was a strange observation, and raises the suspicion that more daylight comets visit our system unobserved than is generally supposed. May it not have been a return of the comet seen a few years ago, in Egypt during a total eclipse of the Sun, and in its immediate neighborhood?

Some of the nebulæ discovered here are very interesting, but cannot be described in detail, a few must suffice. In right ascen-

sion $0^h\ 46^m\ 45^s$ -- Decl. $35°\ 0'.7$, $1^h\ 46^m\ 45^s$ — Decl. $30°\ 26'.3$, $19^h\ 22^m$ — Decl. $36°\ 24'$ are three remarkable objects of which the entire sky affords a very few examples. At first they appear like double stars some 4″ or 5″ apart, but on a close examination with powers of 132 and 200, each component was found to be a stellar nebula like a double nebulous Uranus. In $10^h\ 24^m\ 30^s$ Decl. — $35°\ 3'.4$; $10^h\ 35^m\ 12^s$ Decl. — $35°\ 31'.6$; $13^h\ 31^m\ 10^s$ Decl. — $33°\ 36'$, are also three objects which at first sight appear like the above, but when examined with high powers, only one of each pair was found to be a star, the other an exceedingly small stellar nebula. In $13^h\ 51^m\ 35^s$, Decl. — $39°\ 31'.8$, is a beautiful nebulous star, the only one I have ever discovered, an 8th magnitude star exactly in the center of an exceedingly faint nebulous atmosphere, whose outlines are as sharp as the planet Jupiter. In $3^h\ 31^m\ 0^s$, Decl. — $34°\ 47'$, and $5^h\ 29^m\ .20^s$, Decl. — $36°\ 28'.5$, are two hair-line nebulæ the only ones I have ever seen. With a power of 200 there was no appearance of bulging in the center, but with the closest scrutiny a very slight one could be seen in the middle of the latter by averted vision. They are undoubtedly thin ring nebulæ seen exactly edgewise.

Observing weather at the Lowe Observatory. From April 2d, 1897, the day of my return from the East, till April 2, 1898, the number of clear nights was 299, partly clear 22, cloudy 43, or, an average of 1½ cloudy nights a months. In June and August, every night but two, and in July every night was perfectly clear. The amount of rain fall was 9.92 inches. One peculiarity of this climate is, there are more clear nights than days, exactly the reverse of conditions I found in Rochester. The average clear nights per month was therefore 25.

A brief description of how the right ascensions of my nebulæ were obtained may not be wholly uninteresting. The R. A. circle is loose on the polar axis, but held securely to where set by friction. In front of it, is a circle a little smaller than the R. A. circle, on the circumference of which 480 teeth are cut. To this circle the vernier is attached. Close to the left, is a double spring locomotive clock, on the hour shaft of which is a wheel of 20 teeth, which connects with the vernier circle, this shaft when the clock is running, makes one revolution every sidereal hour by the following device. The break circuit wheel of the Sidereal clock formerly contained 29 teeth, one having been removed. I inserted another in the vacant space. The scape wheel in the little clock was removed, and a pin-wheel escapement of 30 pins was substituted. A short arm is attached to the armature of a telegraph sounder,

which when the electric circuit is closed by a switch works the pin-wheel escapement exactly as the circuit is made and broken by the break wheel in the Siderial clock.

At the commencement of work the switch is closed, the driving clock started, the telescope pointed to, or near the meridian, and the meridional wire in the eye-piece bisected with a mean time nautical almanac star for 1900. The right ascension circle is then set to the right ascension of the star.

When a nebula is found its center by estimation is brought to the meridional wire of the eye-piece, the circle read, its right ascension recorded, ready for publication for the epoch selected, without (if on or near the meridian) making any reduction. Its declination of course is obtained in the usual way. It should be stated that a weighted cord takes up all slack play between the cogs of the vernier circle, and driving pinion of the little clock.

If more exact places for nebulæ are desired, resort must be had to the Filar Micrometer, and even then, an absolute place of a nebula cannot be obtained, unless it be a nebulous star, or, a stellar nebula, as described above.

The right ascension and declination of the Orion nebula never has been accurately obtained. Here let me warn describers of nebulæ against recordng them as stellar, simply because they are small, as Marth and others have too often done. I doubt if I have ever seen a dozen stellar nebulæ, although following the fashion of my predecessors, and to my regret now, some have been recorded as stellar because they were very small. There is as much resemblance between a small and a stellar nebula as there is between the telescopic appearance of Jupiter and Neptune.

As to the variation in brightness of some of the nebulæ, I consider the evidence adduced too weak to advise its discussion to be considered within the domain of astronomical science. The immense magnitude of even the small ones is something figures cannot grapple with. They must many times over fill the entire orbit of Neptune, and therefore to my mind, the mere mention of the character of the evidence in favor of variability, is sufficient for its refutation. I also consider the evidence of change of form equally as unreliable.

THE CLUSTER IN HERCULES.—It is reported that Sir William Herschel has published that there are in this cluster 14,000 suns. After making many examinations of it under the best of conditions, I am constrained to think he has greatly overestimated the number, and that probably the 14 is a misprint for 4, making the number 4,000.

He is also reported to have said to his sister Caroline when he ran across a starless field, "Prepare to write, nebulæ are coming." During my 40 years work on the nebulæ, I find that this assersion does not accord with my experience. The statement is palpably erroneous, and I doubt if he ever made it. It is a fact of universal agreement, that there are no family ties existing between scattered stars and the nebulæ, and therefore, the idea that the presence of stars drive the nebulæ into localities where they are absent, is untenable and at variance with observation.

LIFE IN OTHER WORLDS.

EDWIN C. MASON.

FOR POPULAR ASTRONOMY.

Notwithstanding the progress of scientific knowledge, the genesis of life is as profound a mystery as ever. The perpetuation of life as we know it requires a certain moderate temperature, the presence of moisture, and an atmosphere of some sort, not necessarily however, constituted like that of the Earth; so that whether life originates from certain chemical compositions and combinations now unknown to us, or is the result of the direct act of the Creator, the conditions named must exist, or life in any form cannot continue. We know, to some extent, the physical condition of the planets of the solar system. The magnificent telescopes and splendid equipment of the great Observatories, supplemented by the tireless work of able astronomers, have made this knowledge possible. The planet Mercury, on account of its nearness to the Sun, and the fact that its day and year, like that of the Moon, are of the same length, presents the widely different characteristics of intense heat and more than arctic cold. Like the Moon, one face is constantly towards the Sun. That side must remain continually at a temperature much above the boiling point of water, while the dark side, which never receives any heat except through the body of the planet,—and that refracted by the atmosphere, if there is an atmosphere,—must remain at a temperature much below the freezing point of water. In general terms it may be stated that life cannot exist beyond these limits. There would, it is true, be a small zone of the planet, several miles in width, where these conditions would be modified. The effect of libration, as in the case of the Moon, would be to present a little more than half the surface on one

side or the other alternately to the Sun, but this would not make the planet habitable for beings like ourselves.

In the case of Venus, the same conditions slightly modified prevail. Like Mercury, the day and year of Venus are the same length. While we know that Venus has an atmosphere, and that water exists there, the conditions would not support life as we know it. The Earth's satellite, our nearest celestial neighbor, now claims our attention. Separated from the Earth by a distance less than 300,000 miles, its features and condition can be studied as is true of no other heavenly body.

The first impression of a novice who sees the Moon for the first time through a good telescope, is one of awe. The familiar disc has become a tremendous globe, hanging upon nothing, ready to drop down upon the observer and annihilate him. At favorable times, high magnifying powers reveal the great plains, mountains and valleys of the Moon with almost the distinctness of a distant landscape. No atmosphere and therefore no water exist in the Moon. Not the faintest indications of either has ever been seen. Of course life under such conditions is impossible. It seems almost incredible that so many human beings should have been deceived by the celebrated Moon hoax which was perpetrated in the early part of this century. Astronomers maintained then, as now, that life could not exist in a world which was always as hot as melted lead on one side and as cold as the north pole on the other.

This preposterous story was started for the purpose of testing the gullibility of mankind and it did so very effectively. The Moon was described as being viewed through the great Hershal reflector, which had just been set up in South Africa, where the atmospheric conditions were supposed to be exceptionally favorable. The story related with great detail the wonderful discoveries made under these conditions, describing particularly the Moon's inhabitants, their appearance, daily occupations and dress, which latter, according to the story, would not be called strictly modest, even in these days of the new woman and bloomers.

The next planet to be considered is Mars. In many respects Mars is more suitable for sustaining life than any of the other planets of our system, except the Earth. It has an atmosphere, its day is of nearly the same length as ours, and its distance from the Sun would not render life impossible. Patient watching at favorable times for many years make it certain that Mars is an arid planet. In winter the martian polar snow caps ap-

pear, and in spring they melt away. Those of the Earth, on the contrary, are perennial. There are no indications of any large bodies of water in Mars, and the patches supposed to be seas, vary with the seasons. The proportion of land to water is about three to one.

The Earth's surface is nearly all water, and even under that condition, few parts of the Earth have an undue rainfall. The so-called canals of Mars, it is now believed, are water courses. They are very wide, but undoubtedly very shallow. Their configuration and general direction conform exactly to the theoretical requirements of the supposed conditions prevailing on the planet.

It would not be possible for life to exist under such conditions. Mars is a most disappointing object for the novice to observe through the telescope. He has seen the drawings of the planet in the astronomies, and has read of the canals and snow-caps; he is therefore much surprised when the telescope discloses only an indistinct reddish disc, with no markings whatever.

Repeated observations, however, finally enable a careful observer to decipher the characteristics of the planet. The drawings made by different astronomers correspond with remarkable exactness.

Most people think that all that is necessary in order to see all the wonders of the heavens, is to walk into an astronomical observatory, and take a look through the telescope. They do not know that even at the observatories most favorably situated, there are only about one hundred good observing hours in a year, and that the situation of the planets in their orbits, the time of the year, the atmospheric conditions and the skill of the observer, all have a bearing on the result. Mars is, when on the same side of the Sun as the Earth, only 35,000,000 miles from us. Such a time must be selected for observation—even by the most skillful observer—and the finest instruments must be used, before any of the characteristics mentioned become visible. Between Mars and Jupiter is the belt of asteroids; possibly fragments of a planet which in some great cataclysm of the past has been disrupted. It is impossible to believe that life could exist on these fragments.

Now we come to the planets Jupiter, Saturn, Neptune and Uranus.

All these are yet in a state of incandescence and consequently can not be suitable for living beings. From our knowledge of our solar system, therefore, the Earth seems almost certainly to

be the only planet suitable for sustaining life. How is it beyond the solar system?

It has been mathematically demonstrated that the natural course for a revolving mass of glowing gas, such as our solar system sprung from, would be a splitting into two similar mas ses; each would then revolve around the other. In the case of our solar system a greatly different course followed. Instead of two equal masses, the Sun remained almost intact, abandoning only comparatively insignificant portions from which the planets were developed.

We may, therefore, safely conclude that in any systems beyond ours manifestly composed of two equal or nearly equal members, life would be impossible. Such systems are almost innumerable; but on the other hand there may be thousands of systems like our own in which an enormous central Sun furnishes light and heat to the planets surrounding it. It may well be believed that there must be among all the vast number, some worlds suitable like the Earth for life. However sure we might be that life as we know it is possible beyond the solar system, still there is a great probability that the development of life would not be similar to ours.

In the beginning of life on this Earth, the waters covered much more of its surface than at present. Suppose that when the great saurians crawled out of the water to make their abode on the land, that they had found the mosquitoes as large as swallows, and the ants the size of cats, how long would it have been before the denizens of the water seeking better quarters would have been driven back into their native element?

Development in any of the worlds suitable for life might have taken such paths. The historians and biologists of other worlds may be ants and dragon flies. The Pall Mall Gazette has said recently, "A visit to the Natural History Museum of Brussels and an inspection of the gigantic saurians discovered in recent years, have suggested some curious thoughts in relation to the importance attached by Dr. Munroe to the erect attitude, as the primary cause of intellectual growth and consequent acendency of man. Are we free to believe that had terrestrial conditions remained favorable, lizards would have attained to the lordship of Creation?"

This theory is absurd, as evidenced by the superior intelligence of the ant, and the stupidity of the giraffe. In fact, it seems perfectly comprehensible that a race of alligators might under certain conditions attain to a considerable degree of intellectual su-

periority. Even if life exists in other worlds than this, such an animal as man may be only of this earth; for development is as likely to take ten thousand other courses as this.

We are fond of thinking of ourselves as but little lower than the angels. If we had the bodies of eagles, with our present intellects, would we not be still nearer the angels than now? The fantastic conceit of the author of "The War of the Worlds" is not half as preposterous as it seems.

May it not be possible that when men have succeeded in comprehending and understanding the elusive fourth dimension of space, that we may then see that the infinity of space and creation, now so paralyzing to the human imagination, is entirely within our mental grasp and that so far from being the merest speck in the universe, our world may be the apple of the Creator's eye, and man, in all verity, the very image of God?

MADISON, Wis.

OCCULTATION PHENOMENA.

THOS. LINDSAY.

FOR POPULAR ASTRONOMY.

The occultation of a fixed star by the moon is a phenomenon having a special interest for the amateur who wishes to test for himself the marvelous accuracy claimed for the predictions of mathematical astronomy. He requires only a good portable telescope and a watch, which latter he must, however, have carefully set to the correct time. It is not possible to note the meridian passage of a body in the heavens unless one has a transit instrument properly mounted; no substitute for this would give results worthy of being considered in the discussion of corrections to tabulated places. But in the case of an occultation no delicate apparatus is required, one has only to note the moment of disappearance, and he has a record by which to test the value of the tables of the Moon's position in the heavens. As a matter of fact the errors in the tables are extremely minute; any serious discrepancy between the observed time of an occultation and the time predicted may be set down to some correction to the watch overlooked, until one has had some practice with both watch and telescope, when the discrepancies will disappear.

The ordinary observer then, or even one who is only occasionally interested in telescopic work, looking upon the Moon creep-

ing towards a star has in his field of view an immovable point, which, some three or four years ago, it was predicted that the limb of the Moon would touch. Closer and closer, then out goes the star, and without the aid of those triumphs of mechanical skill, which the astronomer requires in other branches of work, he has verified the accuracy of calculation based on the fundamental laws of the solar system.

It is to be remembered however that the predictions of the ephemeris refer to observations from an inaccessible point, the centre of the Earth, and in the case of the Moon particularly it is quite a tedious operation to reduce the observation to the position of the real observer. And a moment's consideration will show that at no two points on the surface of the Earth will the position of the Moon appear to be exactly the same. Briefly then, in predicting occultations for a given station we are concerned entirely with corrections for parallax.

There will be no difficulty in finding lucid chapters on this subject. It is thoroughly explained in works on practical astronomy and has been brought before the readers of this Journal in clearly illustrated articles. Again, in the American Ephemeris, there is a clear exposition of the method of prediction given in the explanations every year. But after reading all these we still have to admit that the work is tedious, and if we go through the calculations for some half dozen occultations visible at our station, then prepare to observe, only to experience a cloudy night on each and every occasion, we will begin to think that the work is not only tedious, but the results tormenting.

Here in Toronto, the Astronomical and Physical Society has on many occasions made arrangements to observe these interesting phenomena and it is surprising how many records there are of "seeing impossible," "sky very cloudy," etc., etc. The list for visibility will occupy generally about two pages of the ephemeris, and the probable number of favorable occasions ought to be fairly respectable, if it were not for the fact that in this connection the law of probability is a mere delusion. Recently however we have devised a new plan of attack which we recommend to readers of POPULAR ASTRONOMY.

What is the use of going through the work to get the time down to a second if we are not sure of a chance to verify? Is it not better to wait until we have made an observation and then see whether our time fitted in or not? We concluded this was better and henceforth our plan is to be as follows: We have regular gatherings for observation alternating with our indoor meetings

and on these occasions are interested in telescopic work generally, not being yet equipped for work of scientific value; this we hope however soon to reach. But occultation work we can manage very nicely, for we are only a step from the Toronto Observatory and we can go over to get the correction to a watch quite readily. We do not then spend any time in predicting but make efforts to observe accurately and then work out the data, to answer the question, "at that moment, was the Moon by the tables just where it should have been to occult the star?" And to simplify this we have prepared sheets of paper on which the skeleton of the computations is written, from a cyclostyle impression. An example of this here follows. We hope it will be copied, for we feel it is really a good plan for amateur observers.

On the evening of August 30th the immersion of the star θ Aquarii was observed at $8^h\ 37^m\ 37^s$ E. S. T. We adopt the notation of the ephemeris throughout and our paper is headed

Toronto: Geoc. Lat. 43° 27′ 56″
Long. from Washington, + $9^h\ 22^s.61$
$\rho \sin \varphi'$ 9.8368369
$\rho \cos \varphi'$ 9.8601102

(These are constants and are filled in on all the sheets.)

		h	m	s
Wash. hour angle at Geoc. conj.		1	38	
Toronto difference	+		9	22.61
Toronto hour angle at Geoc. conj.		1	47	22.61
Wash. mean time Geoc. conj.		9	56	18
Toronto difference	−		9	22.61
Toronto mean time Geoc. conj.		9	46	55.39
Observed immersion E. S. T.		8	37	37
Correction for Toronto			17	34.65
Mean time of immersion		8	20	02.35
Earlier than Geoc. conj.		1	26	53
In sidereal time		1	27	07
Add hour angle at Geoc. conj.		1	47	22
Hour angle at immersion		3	14	29

(Three of the above lines are constants; "earlier" may be "later," "add" may be "subtract.")

Then, hour angle = h, star's declination = δ

Hour angle in arc $h = 48° 37' 15''$
$\sin h = 9.8752647$; $\cos h = 9.8202272$

$\rho \sin \varphi'$	9.8368369
$\cos \delta$	9.9954443
	9.8322812 = .6796
$\rho \cos \varphi'$	9.8601102
$\sin \delta$	9.1586263
	9.0187365 = .1044

$\sin h$	9.8752647
$\rho \cos \varphi' \sin h$	$9.7353749 = .5437 = \xi$
$\cos h$	9.8202272
$\rho \cos \varphi' \sin \delta \cos h$	$8.8389637 = .0690$
	$.6796 + .0690 = .7486 = \eta$

(Two of the above lines are constants; two are repetitions, and with the last we must be careful regarding the sign.)

Thus we have the coördinates of our station on the disc of the Earth as seen from the star, and to get the coördinates of the Moon's centre we proceed:

Time earlier $1^h\ 26^m\ 53^s$

Reduced to hours, $t = 1.448$;	$\log t$,	10.1607686
$x' = .5522$	$\log x'$,	9.7420964
	$\log x =$	9.9028650
	$x =$	.7995
$y' = .2501$	$\log y'$	9.3981137
	$\log t$	10.1607686
	$\log ty'$	9.5588823
	$ty' =$	.3621
	$Y =$	1.0183
	$y =$	.6562

Then $x - \xi = .2558$; $y - \eta = .0924$ and we have two sides of the triangle which should have for hypothenuse, .27227, that is, the radius of the Moon. Five lines space resolve the triangle.

$\log x - \xi =$	9.4079005
$\log y - \eta =$	8.9656720
	$10.4422285 = \tan 70^\circ\ 8'\ 21''$
$\log \sin 70^\circ\ 8'\ 21'' =$	9.9733682
Deduct from $\log x - \xi$,	$9.4345323 = \log .27198$

Thus we see that at the moment when we observed the immersion of θ Aquarii the star was, according to the tables, already behind the disc; the difference being .00029, almost inappreciable.

Now this result was thought very satisfactory, especially as quite a number of people had the opportunity of watching the approach of the Moon towards the star, until just a few seconds before disappearance and while one of the ladies was counting the seconds. In this particular case the computations had been made beforehand but it is clear that this is quite unnecessary where the object is to get a record of times of immersion observed for comparison with times as predicted. Further, a reference to the ephemeris will show that the predictions for Washington are

given only to the nearest minute. The computers have not considered it necessary to work the results to seconds; this bears us out in our contention that it is better to observe first and compute later, always remembering however that we cannot be too particular about having the watch correct. "A few seconds out," "pretty nearly right," "was right at noon today," none of these will do. We must have the correct time, without any qualifications, else we are not doing justice to those who spend their lives in preparing for us that marvelous book, the Nautical Almanac.

PLANET NOTES FOR NOVEMBER.

H. C. WILSON.

Mercury is evening planet, but will not be visible to the unaided eye until the last days of the month, when one will find the planet near the southwest horizon soon after sunset. Mercury will pass by Uranus, Nov. 11, Saturn, Nov. 18, and Venus, Nov. 20. The conjunction of the four planets is interesting, but all are so involved in the twilight that little can be seen of them.

Venus will come to inferior conjunction Dec. 1, at 11 A. M. central standard time, when Venus will be about one degree south of the Sun's center. Venus will pass by Saturn in retrograde motion Nov. 23. The phase of Venus is now sharply crescent and waning rapidly. Her brightness has just passed its maximum and will decrease very rapidly, becoming invisible to the naked eye a few days before conjunction.

Mars is slowing up in his eastward motion, preparatory to turning westward in December. This planet is now in the constellation Cancer, a little way southeast from Castor and Pollux, the twins, with which it is nearly equal in brightness, They are seen toward the east after midnight. The apparent diameter of Mars will increase during the month from 9″.6 to 12″.0, and the more prominent markings of the surface may be easily seen.

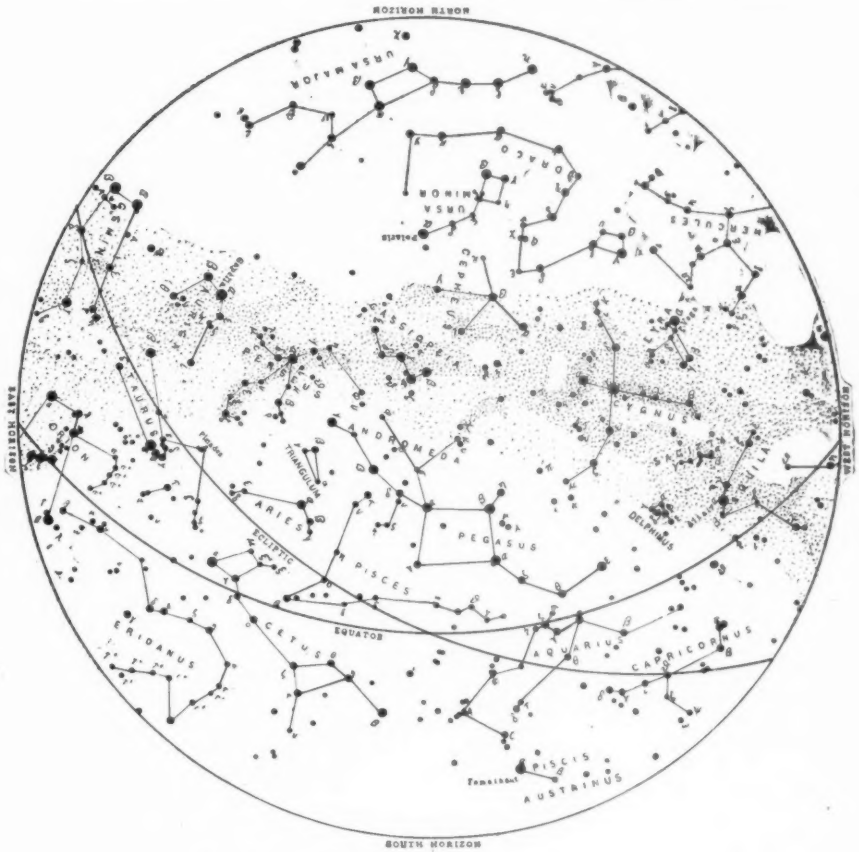
Jupiter is morning planet but is not far enough from the Sun for observation yet.

Saturn and *Uranus* are too deep in the evening twilight to be observed.

Neptune is visible with the aid of a telescope most of the night. His motion is exceeding slow in the constellation Taurus. The position of the planet on Nov. 4 is: R. A. $5^h\ 35^m\ 53^s$; Decl. $+\ 21°\ 59'$.

The Moon.

	Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less.)		Sets.	
		h	m	h	m
Nov. 6	Last Quarter	10	52 P. M.	1	14 P. M.
13	New Moon	6	54 A. M.	4	13 "
20	First Quarter	12	47 P. M.	12	14 A. M.
27	Full Moon	4	01 P. M.	8	6 "



THE CONSTELLATIONS AT 9 P. M., NOVEMBER 1, 1898.

Occultations Visible at Washington.

Date 1898.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.		Angle from N pt.	EMERSION. Washington M. T.		Angle from N pt.	Duration.	
			h	m	°	h	m	°	h	m
Nov. 2	10 Geminorum	7.0	7	44	64	8	33	293	0	49
2	11 Geminorum	7.3	7	52	96	8	45	261	0	53
6	*o* Leonis	3.8	12	20	121	13	21	278	1	1
17	50 Sagittarii	5.9	4	51	46	6	0	269	1	9
24	101 Piscium	6 3	6	19	73	7	33	224	1	14
25	μ Arietis	6.0	16	8	58	17	1	286	0	53
27	62 Tauri	6.0	13	12	60	14	29	296	1	17
28	103 Tauri	6 0	7	2	119	7	52	221	0	50
29	9 Geminorum	6.3	16	47	57	17	33	236	0	46
29	10 Geminorum	7.0	17	54	57	18	36	335	0	42
29	11 Geminorum	7.3	18	2	85	19	2	307	1	0

Witt's Planet DQ.—One of the most important astronomical discoveries of recent years is the finding of the planet DQ, by Witt. This object will come nearer to the Earth than any other similar object, except the Moon. Its minimum distance is about 15 million miles, and the corresponding parallax nearly a minute of arc. To determine the photometric brightness of this object, the stars — 6°5567, — 6°5579, — 6°5600, — 6°5608, and — 6°5626 were each measured on five nights with the meridian photometer, eight settings being made each night, with the resulting magnitudes, 7.87, 8.65, 8.71, 8.56, and 9.57 respectively. The probable error of these values varies from ± 0.020 to ± 0.033. The brightness of the stars, — 6°5550, — 6°5560, and — 6°5588 was later determined differentially from these, with the resulting magnitudes 8.80, 9.89, and 8.37. Mr. Wendell compared the planet on six nights by means of the photometer with achromatic prisms attached to the 15-inch equatorial. The number of settings on each night was 48. On September 5 and 6, 1898, it was compared with — 6°5626, on September 9 with — 6°5608, on September 12 with — 6°5579, and on September 13 and 14 with — 6°5588. The resulting magnitudes were 12.19, 11.97, 12.10, 12.01, 12.20, and 12.29. Mean, 12.13 ± 0.04. As the logarithms of the distances of the Sun and Earth, on the mean date, September 10, were 0.2366 and 9.9115, the magnitude when these distances are both unity becomes 11.39.

It is not easy to obtain photographs adapted to determining the photographic brightness of this object, owing to its faintness and rapid motion. With a short exposure the image is very faint, and with a long exposure a trail is obtained which cannot be compared with the circular images of adjacent stars. Measures of the photographic brightness have been made by Mrs. Fleming on plates taken with the 8-inch Draper telescope, and having exposures of about 15 minutes. The planet was not far distant from the variable star T Aquarii and was compared with four of its comparison stars whose photometric magnitudes had already been determined. Plates taken on September 6, 12, 13, 13, 13, 13, 14, 17, 20, and 21, 1898, gave the magnitudes 12.78, 12.75, 12.80, 12.85, 12.78, 12.75, 12.75, 12.72, 12.65, and 12.68. Mean, 12.75 ± 0.01. Similar measures of two isochromatic plates taken on September 17 and 20 gave the magnitudes 12.80 and 12.61. Mean, 12.70 ± 0.08. Since the planet is fainter photographically than photometrically, it is probable that its color, like that of the Sun, is redder than an average star.

Several interesting photometric problems present themselves in connection with this object. First, the approximate diameter may be determined by comparison with the brighter asteroids and satellites, assuming that the reflecting power is the same. Secondly, the great variation in the distance of this object from the Earth will afford an excellent test of the law that the light varies inversely as the square of the distance. The existence of an absorbing medium in the solar system will thus be tested. Thirdly, owing to the proximity of this object to the Earth at opposition, its phase angle will vary by a large amount. It will, therefore, afford an excellent test of the law connecting this angle with the variation in brightness, which has been found by two or three observers independently.

EDWARD C. PICKERING.

Harvard College Observatory, Circular No. 34,
September 30, 1898.

Ephemeris of Planet 1898 DQ.

[From *Astronomische Nachrichten*, No. 3510.]

1898	α app. h m s	δ app. ° ′	log r	log Δ
Nov. 1	20 57 50	− 4 56.9		
3	21 0 22	4 47.8		
5	3 1	4 38.3	0.2043	0.0805
7	5 46	4 28.2		
9	8 36	4 17.6		
11	11 32	4 6.4		
13	14 34	3 54.7	0.1983	0.1008
15	17 41	3 42.4		
17	20 53	3 29.5		
19	24 11	3 16.1		
21	27 33	3 2.2	0.1919	0.1192
23	31 0	2 47.7		
25	34 31	2 32.6		
27	38 6	2 17.0		
29	41 46	2 0.9	0.1852	0.1359
Dec. 1	21 45 30	− 1 44.2		

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1898.

U CEPHEI.

	d	h
Dec.	4	13
	9	12
	14	12
	19	12
	24	11
	29	11
	31	23

ALGOL.

	d	h
Dec.	1	18
	4	15
	7	12
	10	9
	18	23
	21	20
	24	17
	27	14
	30	10

λ TAURI.

	d	h
Dec.	4	16
	8	15
	12	14
	16	12
	20	11
	24	10
	28	9
	32	8

R CANIS MAJORIS.

Every 8th min.

$P = 1^d\ 3^h.3$

	d	h
Dec.	1	10
	10	12
	19	14
	28	16

S CANCRI.

	d	h
Dec.	6	0
	15	11
	24	23

S VELORUM.

	d	h
Dec.	5	13
	11	12
	17	10
	23	8
	29	7

LIBRÆ.

	d	h
Dec.	19	19
	26	18

U CORONÆ.

	d	h
Dec.	7	16
	14	14
	24	22

Y CYGNI.

Even min.

	d	h
Dec.	1	7

Odd min.

	d	h
Dec.	2	10

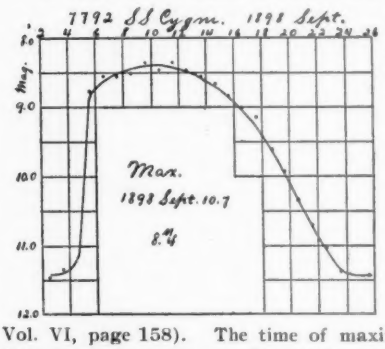
W DELPHINI.

	d	h
Dec.	12	10

Y CYGNI. The minima are now visible only in European longitudes. The first minimum in each class is given above, the others follow every third evening, about five minutes earlier.

EPHEMERIS OF LONG PERIOD VARIABLES. No ephemeris for 1899 has yet appeared, and it would not be worth while to duplicate the work done in this line by Drs. Chandler and Hartwig; but it is hoped that one will be published in time for the November number.

SS CYGNI. The September maximum was so thoroughly covered by the observations of Mr. Zaccheus Daniel that a good chance was offered for comparison with the maxima of last season. The accompanying light curve, based upon 20 observations by Mr. Daniel and 8 of my own, show that it was a typical "long" maximum, differing from those of 1897 only in the maximum magnitude, and that by only 0.1. On Sept. 11 and 13 Mr. Daniel estimated the variable one step brighter than the comparison star *b*, to which was assigned the magnitude 8.46 (see Vol. VI, page 158). The time of maximum from the present curve is Sept. 10.7, but if the mean curve deduced from the long maxima of 1897 is applied to the observed magnitudes, the time of maximum comes out Sept. 9.6. The rise began Sept. 4 after a normal period of 36 days, the usual interval following a "short" maximum such as that of July 21. The variable remained above normal 19 days. The interval since the last maximum was 50.9 days (or 49.8 if the maximum be taken from the mean curve). The star passed 9.35 magnitude, rising, about Sept. 5.4 (from mean curve), the interval since the last similar passage being 47.0 days.



TWO NEW VARIABLES. In No. 3512 of the *Nachrichten*, Professor Ceraski, of Moskow, announces the discovery, from photographs, of a variable in the place—from eye estimates—

R. A. $21^h\ 6^m.9$, Decl. $+ 82°\ 28'.0$, (1855)

Professor Ceraski reports the star 10th magnitude and fading 1898 July 25. At present there is nothing as bright as the 12th magnitude near the indicated place. When the star becomes brighter the identification will be made easy by the two neighboring Durchmusterung stars—

	Mag.	R. A.	Decl.	
a	8.5	$21^h\ 8^m\ 23^s$,	$+ 82°\ 24'.5$	(1855)
b	9.3	7 0	25 .1	"

The second new variable was discovered by Rev. Thomas D. Anderson, of Edinburgh, and announced in No. 3520 of the *Nachrichten*. Its place from eye estimate is—

R. A. $20^h\ 5^m.9$, Decl. $+ 12°\ 33'$, (1855)

Anderson found it 9.3 magnitude 1898 Aug. ?; 9.8 magnitude Aug. 27; and 10.4 magnitude Sept. 11. I found a 12.2 magnitude star wihtin 0'.5 of the indicated place Oct. 8.

MIRA became visible to the naked eye earlier than was anticipated this season, and bids fair to pass a very bright maximum. A fine series of spectrum plates was taken with the 40-inch Yerkes telescope during the last maximum. This will be supplemented by an improved series this season, as with the sensitive plates now used the spectrum can be photographed about as far into the red as the visible spectrum extends. The record thus obtained of the star's changes will be of great importance, and the results which will appear in the *Astrophysical Journal*, will be awaited with much interest.

COMET NOTES.

New Comet *i* 1898 (Brooks).—A new comet was discovered by W. R. Brooks, at Smith Observatory, Geneva, N. Y., on the evening of October 20. Its position Oct. 20.5000 Greenwich mean time was: Right Ascension $14^h\ 32^m\ 10^s$; Declination $+ 60°\ 26'$. It is thus an evening comet and is moving toward the southeast. It is described as bright and round in shape.

The following observations of the comet are at hand, those by Professor Hussey having been telegraphed to Boston and thence communicated by mail through the courtesy of Mr. John Ritchie and of Harvard College Observatory:

Observer	Greenwich M. T.	App. α h m s	App. δ ° ′ ″
Hussey	Oct. 21.6352	15 03 35.6	+ 57 55 18
Wilson	22 6900	15 25 39.0	+ 55 19 33
Hussey	23 6280	15 42 57.1	+ 52 49 22
Wilson	25.5426	16 12 22.3	+ 47 20 10

As soon as I had obtained the observation on Oct. 25, and before that on the 23rd had come to hand, I computed the following rough elements which represent the observations on Oct. 21, 22 and 25 as closely as could be expected from four place logarithms:

$T = 1898$ Nov. 23, 12 Gr. M. T.
$\omega = 122° 25'$
$\Omega = 94\ 55$
$i = 140\ 4$
$q = 0.7558$

These elements give the following ephemeris:

Greenwich Midnight.	α h m s	δ ° ′	log r	log Δ	Brightness.
Oct. 20	14 37 00	+ 60 25	9.9980	9.7933	1.00
24	15 57 12	+ 50 22	9.9772	9.7881	1.13
28	16 45 24	+ 38 34	9.9568	9.8103	1.12
Nov. 1	17 14 54	+ 27 38	9.9376	9.8522	1.01
5	17 33 54	+ 18 29	9.9196	9.9034	0.86
9	17 47 0	+ 11 9	9.9042	9.9566	0.73
13	17 56 0	+ 5 14	9.8916	0.0077	0.61

The comet is thus moving southeastward rapidly through the constellation Hercules. It is easily seen in bright moonlight with a telescope. According to these elements the comet has passed its nearest approach to the Earth and its maximum brightness but will not reach perihelion until November 23.

Elements of Comet *i* 1898 (Brooks.)—The following elements and ephemeris, computed by Professor Hussey, of Lick Observatory, have just been received by telegram from Mr. John Ritchie, Jr., of Boston. They were computed from observations Oct. 21, 23 and 25.

ELEMENTS.

$T = 1898$ Nov. 23.14 Gr. M. T.
$\omega = 123° 22'$
$\Omega = 96\ 10$
$i = 140\ 19$
$q = 0.7564$

EPHEMERIS.

Greenwich Midnight.	α h m s	δ ° ′	Brightness.
Oct. 27	16 35 48	+41 31	1.08
31	17 9 8	+30 11	
Nov. 4	17 30 28	+20 30	
8	17 44 52	+12 41	0.63

Ephemeris of Wolf's Comet 1898.

[From *Astronomische Nachrichten*, No. 3518.]

1898.	α h m s	δ ° ′	log r	log Δ	Ab.-Time. m s	Brightness.
Nov. 1	7 7 6	−6 29.3				
2	7 26	6 48.2	0.2987	0.1579	11 56	2.63
3	7 44	7 6.9				
4	8 0	7 25.6	0.3011	0.1561	11 53	2.62
5	8 14	7 44.1				
6	8 26	8 2.4	0.3035	0.1545	11 51	2.61
7	8 35	8 20.6				
8	8 42	8 38.7	0.3058	0.1530	11 48	2.60
9	8 47	8 56.6				
10	8 50	9 14.3	0.3082	0.1516	11 46	2.59
11	8 50	9 31.8				
12	8 49	9 49.3	0.3105	0.1503	11 44	2.58
13	8 46	10 6.4				
14	8 40	10 23.4	0.3129	0.1490	11 42	2.57
15	8 32	10 40.1				
16	8 22	10 56.6	0.3153	0.1480	11 40	2.55
17	8 10	11 12.8				
18	7 55	11 28.8	0.3176	0.1471	11 39	2.53
19	7 39	11 44.5				
20	7 20	11 59.9	0.3200	0.1463	11 37	2.51
21	6 59	12 15.0				
22	6 37	12 29.9	0.3223	0.1457	11 36	2.49
23	6 13	12 44.5				
24	5 47	12 58.8	0.3247	0.1453	11 35	2.47
25	5 19	13 12.7				
26	4 49	13 26.3	0.3270	0.1450	11 35	2.45
27	4 15	13 39.5				
28	3 41	13 52.5	0.3294	0.1449	11 35	2.43
29	3 5	14 5.0				
30	7 2 28	−14 17.3	0.3317	0.1450	11 35	2.40

GENERAL NOTES.

Discovery of Comet Brooks 1898.—While sweeping the northern heavens last evening I discovered a new comet, in the constellation Draco. Its approximate place October 20th, 7 hours, standard mean time, was R. A. 14 hours, 35^m 10^s; declination north 60° 26′. This of course makes it circumpolar, and I was fortunate to secure a second observation this morning through breaks in the clouds, just before dawn. Its position at that time was as follows:

October 20th, 17 hours, R. A. 14^h 46^m 30^s; + 59° 32′.

The comet is of good size, round, with a minute stellar nucleus. It is a conspicuous object in the 10-inch refractor.

WILLIAM R. BROOKS.

SMITH OBSERVATORY, Geneva, N. Y.

October 21, 1898.

Comet Brooks was observed this evening, Oct. 22, at $7^h\ 12^m$, Standard mean time, in R. A. $15^h\ 22^m\ 30^s$; north declination $55°\ 52'$. Conspicuous in 10-inch refractor in presence of a half moon. Easy in the 3-inch finder. Comet appears brighter than at discovery. WILLIAM R. BROOKS,

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Comet III, 1862.—In the September POPULAR ASTRONOMY, Lewis Swift, if the writer reads his remarks correctly, claims to be the original discoverer of Comet III, 1862. He states that a comet which he saw on the evening of July 15th had a *tail*. Now, let us look "at the other side of the case." The comet which the writer discovered at the Harvard College Observatory on the evening of July 18th, 1862, had *no tail* nor any sign of one at that time, either in the 4-inch comet-seeker nor in the 15-inch telescope. The field of view in the comet-seeker was over three degrees and in the equatorial one quarter of a degree. Had there been the slightest trace of a tail on that evening either myself or Professor Bond would have certainly seen it. Professor Bond saw the comet in the 4-inch comet-seeker in less than ten minutes after the writer first observed it, and a few minutes later he was observing it with the great telescope. Had there been the slightest trace of a tail to the comet in either of these instruments one or both of us would most likely have seen it. If the comet seen by Swift on July 15th was the same one that was observed at Cambridge on July 18th, and its *position in right ascension and declination accurately recorded*, what had become of its "tail" in the mean time? Had it been playing the pranks of the Holmes' comet of after years?

It is not a little remarkable that in a letter of Swift's, written to Professor Bond, in the latter part of July, 1862, claiming the priority of discovery of this comet, he made no mention that the comet had a tail. In conclusion the writer will only say that the highest authority on astronomical matters in this or any other country, knowing all the facts relating to the *original* discovery and *observations* of this comet, has given the credit of the discovery to Harvard College Observatory, and there it will remain for all time among unbiased American astronomers.

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tions to accompany the article. The numbers in two rows below in the first cut will help to identify about five-sixths of that group of sixty-three persons.

The numbers below stand opposite the names of persons as far as known. With the cut before the reader begin at the left hand and follow to right consecutively, in order given below. Lower row of figures means people in front.

The first unknown.
1. S. I. Bailey.
2. J. M. VanVleck.
3. John Stein.
The next not known.
4. Albert S. Flint.
5. Mrs. J. W. Eddy.
6. Winslow Upton.
7. Geo. E. Hale.
8. Chas. R. Cross.
The next not known.
9. N. E. Bennett.
10. Wm. M. Reed.
11. Miss M. R. Donaghe.
12. Frank M. Very.
13. Miss E. F. Gill.
14. H. M. Paul.
The next not known.
15. W. H. Pickering.
16. J. G. Hagen.
17. Mrs. M. Fleming.
18. C. G. Abbott.
19. Miss I. E. Woods.
20. Miss M. C. Spevens.
21. John A. Dunne.
22. J. F. Hayford.
23. H. M. Goodwin.
24. Lawrence LaForge.
25. Miss A. C. Maury.
26. A. G. Webster.
27. Miss E. G. Wolffe.
28. B. O. Pierce.
29. Alex Macfarlane.
30. H. M. Parkhurst.
31. G. W. Meyers.
32. Miss Sarah Whiting.
33. Edgar Frisby.
The next two unknown.
34. G. W. Hough.
35. A. N. Skinner.
The next two unknown.
36. W. H. Collins.
Next not known.
37. A. E. Dolbear.
38. G. C. Comstock.
39. Miss Ida Griffiths.
Next not known.
40. S. H. Brackett.
41. M. B. Snyder.
42. J. T. Rover.
43. D. C. Miller.
44. W. R. Warner.
45. H. W. DuBois.
46. O. C. Wendell.
47. E. C. Pickering.
48. C. Lundin.
49. A. W. Quimby.
50. A. Searle.
Next not known.
51. R. H. Frost.
Last not known.

Brilliant Meteor.—It may be of interest to the readers of POPULAR ASTRONOMY to know that a remarkable meteor was seen at this place, this evening at about six o'clock. When first seen, it was low down in the southwest near the star α Piscis Australis (Fomalhaut). It moved rather slowly to the northwest, and faded from view beyond the star α Coronæ Borealis, having been in sight for more than 120° of its path. The night was clear and the Moon shone very brightly, nevertheless the meteor appeared very bright and its train was brilliant for about 20° behind the body. Close behind the head were several bright fragments of minor bodies all in line. The meteor was in view for about twelve seconds.

O. M. LELAND.

Tallahassee, Florida, Oct. 22, 1898.

Corrigendum.—In POPULAR ASTRONOMY for March, 1898, on page 6 and on line 8, counted from the bottom, of the page, and between the words "have" and "discovered," insert the word "*independently*."